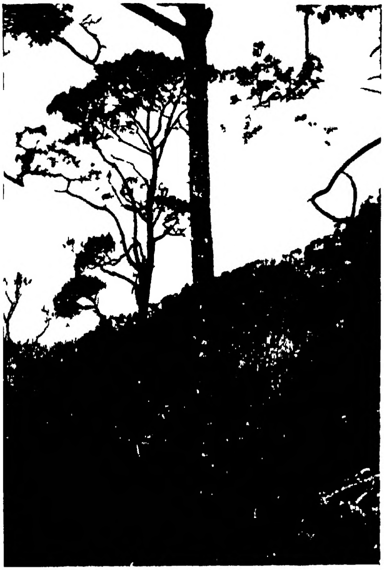
as the effect of a superimposed right-handed twist and as such is dealt with later. It is during this stage that the indications of the bark-striation will not agree with those of the outermost layers of wood, nor the latter with the condition of the bole as a whole. This variation with age may also frequently be recognised on the two tangentially cut surfaces of a sawn scantling. (Fig. 15 A and B.).

RIGHT-HANDED TWIST.

Right-handed twist is, as already mentioned, less frequently met with than the opposite case, but is very probably commoner than is generally recognised, especially in virgin forests containing a large proportion of overmature trees (Figs. 6 and 9). The type is virtually confined to large mature and overmature trees, and is to be expected in the usually good class of locality producing crops of such trees (SMYTHIES[21] p. 11). The twist is almost invariably found to be restricted to the outer layers of wood, becoming more intense centrifugally (as in *Punica*), the inner core being straight, or sometimes with a left-handed twist (cf. *supra* and Fig. 6) ; no case has been noted of any pronounced swelling of the base of the bole. CANNING[19] and LAMBERT (*in litt.*) record that in their experience in E. Almora, the degree of twist becomes more intense upwards in the bole, but this tendency appears to be less pronounced than is the converse for left-handed twist : in fact, although this increased twist may be accepted as the general rule, especially well up in the crown of the tree, figures similar to those quoted above for left-handed trees are most frequent.

In the few cases met with of a right-handed twist in young poles, the inclination of the fibres is very slight and only apparent over certain portions of the stem. Although earlier observations on 2716 two-year old seedlings indicated an almost complete absence of right-handed twist at this stage, some 1 year old plants have been found shewing this form of abnormality 31 definitely, and 62 slightly out of 1387 examined [cf. Fig. 28 (13) (22-21)]. These figures correspond to 0 per cent. for the 2-year olds, and 0·2 per cent. or 0·4 per cent. for the 1-year-olds from the same sowings. Right-handed twist has not been found in young natural coppice shoots with the exception of one lot mentioned on p. 26 and illustrated in Fig. 11 ; here however it was quite pronounced.

A connection may perhaps be recognised between the absence of right-handed twist in the young tree with active height growth, and its tendency to put in an appearance in old trees in which height growth has virtually ceased (Canning), and to reach its maximum expression in the



A dead standing tree shewing right hand twist [illegible]
Khal [illegible] Alm[illegible]

The lower part [illegible] the same
tree with [illegible] hand twist

10. A typical strongly left [illegible] Dehra Dun [illegible]
[illegible]

THE

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CONTENTS OF VOLUME XI.

INDIAN FOREST RECORDS

Vol XI 1924 **Part I**

THE CONSTITUENTS OF SOME INDIAN ESSENTIAL OILS.

PARTS XIV XV.

JOHN LIONEL SIMONSEN.

PART XIV.

The Essential oil from the Seeds of *Zanthoxylum ovalifolium.*

In previous parts of this series of papers the constituents of the essential oils separated from the seeds of *Zanthoxylum alatum. Z acanthopodium* and *Z. Budrunga* were described (Ind. For. Rec 1922, *IX*, 133 141) and it is now possible to extend our knowledge of the essential oils present in this species by an account of that contained in the seeds of *Zanthoxylum ovalifolium.*

Z. ovalifolium would appear to be fairly widely distributed in the Indian Peninsula but it is doubtful if it is found anywhere in sufficient quantity to warrant the collection of the seeds for separation of the essential oil. It occurs in the Sikkim Terai, and outer valleys, ascending to 3,000 feet. Assam. Khasi Hills. Kachin Hills. the Western Ghats from South Kanara to Tinnevelly up to 1,000 feet. It is also found in the Andamans. The seeds used in this investigation were obtained from the Siddarpur Range of the Honawar Division and the author is much indebted to Mr. M. S. Tuggase, the Officer in charge of the Honawar Sub-Division of Kanara, for the great trouble which he has taken to collect botanical specimens and for arranging for the supply of the seed in quantity.

The oil, which was separated from the seeds by distillation in steam in the usual manner, was a yellowish brown oil possessing a fragrant smell. The yield of the oil from the whole seed and husk was approximately 0·3 per cent.

An examination of the oil has shown it to consist essentially of a hydrocarbon boiling at 164-165°/705mm. and a substance boiling at 162-163°/100mm. The hydrocarbon, which only showed very slight optical activity, was found to consist of practically pure myrcene, which was identified by reduction to dihydromyrcene and conversion of the latter by treatment with bromine into the characteristic tetrabromo derivative melting at 88°. The trace of optically active hydrocarbon present in the oil was probably *l*-phellandrene, since a higher boiling intermediate fraction yielded a small quantity of a crystalline nitrosite melting at about 103°. It was not obtained in sufficient amount to render purification possible.

The second main constituent of the oil was found on analysis to have the formula $C_{10}H_{10}O_2$ and was identified as safrol by oxidation with potassium permanganate to piperonylic acid melting at 228°. This fraction of the oil showed slight optical activity but the substance to which this was due could not be separated.

A small high boiling fraction was also obtained which appeared to consist of a sesquiterpene alcohol but it was not obtained pure and did not yield any crystalline derivatives.

In addition to the substances mentioned above, palmitic acid was also found to be present in the oil as well as a trace of a liquid phenol which gave a deep red colouration with ferric chloride. The acids present in the oil in a combined state which were volatile in steam, from an analysis of the silver salt, consisted apparently of a mixture of butyric (or *iso*butyric) and valerianic (or *iso*valerianic) acids.

It is interesting to note the wide differences in the constituents of the oils present in the seeds of the species of *Zanthoxylum* occurring in India which have so far been examined.

TABLE I.

Species.	*Chief constituents.*
Z. [illegible]	*l*-α-phellandrene, linalol.
Z. [illegible]	dipentene, *l*-α-phellandrene, *d*-linalol, methyl cinnamate.
Z. [illegible]	*l*-sabinene.
Z. [illegible]	myrcene, safrol.

EXPERIMENTAL.

As has already been mentioned the oil was separated by distillation in steam of the whole seed. Preliminary experiments indicated that the

oil was only present in the husk but it was found more convenient to distil the whole seed. The oil was somewhat viscid and yellowish brown in colour; it had the following constants:—D^{30}_{30} 0·9381, N^{30}_{D} 1·1995, $[\alpha]^{30°}_{D}$ -0·55°, acid value 5·73, saponification value 14·57, saponification value after acetylation 27·11.

A quantity of the oil was washed successively with dilute sodium carbonate solution * and sodium hydroxide solution (10 per cent.) and finally heated on the water bath for a short time with a dilute alcoholic solution of potassium hydroxide to hydrolyse any esters present. The three alkaline solutions were reserved for later examination.

The oil recovered from the hydrolysis was distilled under diminished pressure (100mm.) when the following fractions were obtained :-

TABLE II.

No	B. P. (100mm.)	$D^{30°}_{30°}$	$N^{30°}_{D}$	$[\alpha]^{30°}_{D}$	Yield per cent. (calculated on the original oil).
I . . .	108-120	0·8067	1·47	—0·55	30
II . .	120-140	0 8369	1·4762	—0 94°	8·3
III . . .	140-160°	0·9248	1·496	- 1·35	2·4
IV . . .	160-185	1·0683	1 5277	--1 68	40 1
V . . .	185-210	1 0532	1 5278	-- 2 45	4·6

Myrcene.

The first three fractions were systematically redistilled under diminished pressure (100mm.) when practically the whole was found to pass over at 101-105 /100mm. and after distillation over sodium the following constants were observed :- D^{30}_{30} 0·7856, N^{30}_{D} 1·466, $[\alpha]^{30}_{D}$ 0·12°. The oil, which possessed a fragrant smell, boiled at 161-165°/705mm. and from its physical constants appeared to consist of an alicyclic hydrocarbon, the slight optical activity being evidently due to a trace of an impurity.

The hydrocarbon was identified as myrcene by its reduction to dihydromyrcene. In one experiment the terpene (10 grammes) was

* During the washing with sodium carbonate solution a sparingly soluble sodium salt separated which was filtered off and added to the aqueous extract.

PART XV.

The Essential oil from the Seeds of *Juniperus communis*.

Juniperus communis is a small evergreen shrub which is found very widely distributed. According to Troup (Silviculture of Indian Trees, Vol. III, 1166) it occurs " throughout the northern and central part of Europe, at the higher elevations of the Mediterranean region, and eastward through Siberia, Persia, Afghanistan, Kurram valley at 11,000—13,000 feet, and the western Himalaya at 5,500—14,000 feet extending eastward to Garhwal and Kumaon, where it occurs only at the higher elevations."

Oil of Juniper is obtained by the distillation in steam of the berries but much of the oil of commerce according to Parry. (The Chemistry of Essential Oils, Vol. I, 33) is probably not normal in composition being obtained as a by-product in the manufacture of gin and similar spirits.

It appeared of interest to examine the oil obtained from the berries grown in India and through the kindness of the Divisional Forest Officer, Upper Bashahr Division, Nichar, a quantity of the berries were obtained and the oil separated by distillation in steam. Unfortunately the yield of oil was extremely poor, approximately 0·2 per cent, but sufficient was obtained to show that it differed somewhat in its composition from the normal Juniper oil. Oil of Juniper, which is as a rule laevorotatory, has been shown to contain α-pinene, camphene, terpinenol, *l*-cadinene and high boiling oxygenated bodies.

The oil examined by the author was found to consist of about 50 per cent. of *d* sabinene, terpineol, a small amount of *l*-cadinene and a considerable quantity of high boiling oils which analysis showed to be a mixture of oxygenated bodies probably sesquiterpene alcohols. α-Pinene, which is stated to be present to the extent of 25-35 per cent. in the normal oil, could not be detected, whilst *l*-cadinene was only present in traces and was identified by its colour reactions with sulphuric acid and by the preparation of the dihydrochloride and dihydrobromide.

The oil, therefore, resembles in its composition oil of savin which is distilled from the twigs of *Juniperus sabina*, since the principal constituents of this oil have been shown to be *d*-sabinene, sabinol and cadinene.

Owing to the inaccessable regions in which *J. communis* occurs in India it is hardly likely that it could be used as a commercial source of oil of Juniper.

EXPERIMENTAL.

The oil, which was somewhat deeply coloured, had the following constants :—$D^{30°}_{30°}$ 0·8788, $N^{30°}_{D}$ 1·478, acid value 5·9, saponification value 21·2, saponification value after acetylation 49·1. It was too deeply coloured for an accurate determination of its rotation. It will be observed that the physical constants agree fairly well for those which have been found for normal oil of Juniper obtained from berries grown in Europe since Parry (loc. cit., 34) gives the following values :— D 0·865 to 0·890, N_D 1·475 to 1·4880, α_D—3° to —20°, acid value 1 to 4, saponification value 2 to 8, saponification value after acetylation 15 to 25.

Prior to distillation the oil was washed with sodium carbonate solution to remove the free acids and boiled with an alcoholic solution of potassium hydroxide to hydrolyse the esters present, the alkaline solutions being reserved for later investigation. On distillation of the neutral oil under diminished pressure (100mm.) the following fractions were separated a somewhat large residue remaining in the distilling flask.

TABLE I.

No.	B. P. (100mm.)	$D^{30°}_{30°}$	$N^{30°}_{D}$	$[\alpha]^{30°}_{D}$	Yield per cent. (calculated on the original oil).
I . . .	98-120°	0·8388	1·4653	+70·85°	54·2
II . . .	120-160°	0·8715	1·4763	—*	7·3
III . . .	170-190°	0·9222	1·4965	—*	5·2
IV . . .	above 190°	0·949	1·5033	— 7·3°	20·8

The first two fractions were redistilled when three main fractions were obtained.

TABLE II.

No.	B. P. (100mm.)	$D^{30°}_{30°}$	$N^{30°}_{D}$	$[\alpha]^{30°}_{D}$	Yield per cent.
1 . . .	99-105°	0·8386	1·464	+78·1°	42·7
2 . . .	105-112°	0·8406	1·4675	+59·6°	8·3
3 . . .	112-140°	..	..	..	6·3

(*These fractions were not available in sufficient amount for the determination of the rotation.)

Fraction 1. *d*-Sabinene.

This fraction, which formed the main bulk of the oil, boiled at 162-165°/702mm. and was identified as *d*-sabinene by oxidation with potassium permanganate in the usual manner to *d*-sabinenic acid which melted at 55-57° and was obtained in an excellent yield.

0·1181 gave 0·2812 CO_2 and 0·0904 H_2O C=64·9 H=8·5
$C_{10}H_{16}O_3$ requires C=65·2 H=8·7 per cent.

An examination of the oxidation acids yielding readily soluble sodium salts failed to reveal the presence of pinonic acid and hence α-pinene was probably absent.

Fraction 2.

The only hydrocarbon which could be detected in this fraction was *d*-sabinene.

Fraction 3.

The yield of this fraction was extremely small. It possessed a marked odour of hyacinth and was found to contain a considerable quantity of terpineol since it yielded on treatment with amyl nitrite terpineol nitrosochloride melting at 107-108°.

Fraction IV (Table I) *l*-Cadinene.

This fraction consisted of a somewhat viscid yellow oil, which, when dissolved in acetic anhydride and treated with a drop of sulphuric acid gave the beautiful series of colour changes which are characteristic of cadinene. The presence *l*-cadinene was established by the preparation of the dihydrochloride which after crystallisation from alcohol melted at 117-118° and in chloroform solution the rotation was found to be —24·01°.

The dihydrobromide melting at 124—125° was also prepared and analysed.

0·1006 gave 0·1002 AgBr Br=43·3.
$C_{15}H_{26}Br_2$ requires Br=43·7 per cent.

Fraction V.

This fraction, which after the removal of the *d*-sabinene was the largest fraction, was a very viscid yellow oil. It was redistilled at 20 mm. pressure when it was not found possible to separate any substance of constant boiling point, the oil distilling irregularly between 150—220°. Four separate fractions were collected and analysed ; (*a*) 150—170° (C=83·9, H=11·3), (*b*) 170-180° (C=81·4, H=11·3), (*c*) 180-200° (C=79·1,

H=10·4) (*d*) 200-220° (C=82·8, H=11·1). These analytical figures indicated clearly that the oil was a mixture of alcohols but owing to the limited quantity of material available further purification was impracticable.

Free acids.

The sodium carbonate extract of the original oil (see above) was extracted with ether to remove traces of neutral oil and acidified when a viscid oil separated. This was taken up with ether; the ether dried and evaporated when a crystalline solid remained. After draining on porous porcelain to remove a little adhering oil, the acid was crystallised from methyl alcohol from which it separated in leaflets melting somewhat indefinitely from 59-61°. A titration with standard alkali gave a molecular weight of 246 indicating that the acid was a mixture of palmitic acid (M=232) and stearic acid (M=284).

Combined Acids.

From the alkaline solution resulting from the hydrolysis of the esters present in the oil, a mixture of acids was separated by distillation in steam. The distillate was collected in two fractions and the silver salts were prepared and analysed.

Fraction I.

0·1673 gave 0·098 Ag Ag = 58·6.
$C_3H_5O_2Ag$ requires Ag = 59·5 per cent.

Fraction II.

0·1761 gave 0·0937 Ag Ag = 53·2.
$C_4H_7O_2Ag$ requires Ag = 55·4 per cent.
$C_5H_9O_2Ag$ requires Ag 51·7 per cent.

From these results it may be deduced that the combined acids present in the oil consisted of a mixture of propionic, butyric (or *iso*butyric), and valerianic (or *iso*valerianic) acids.

The author is much indebted to his assistants Messrs. Gopal Rau and Ghose for their assistance in the analytical work required in this and the preceding paper.

FOREST RESEARCH INSTITUTE,
DEHRA DUN

March 1924.

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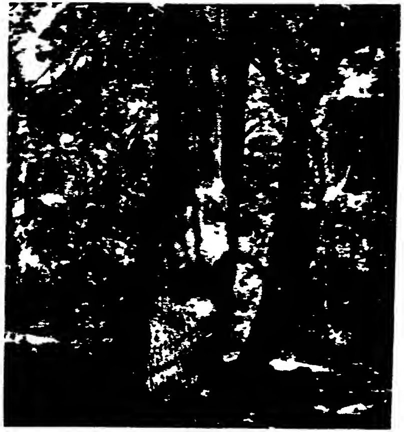
CHAMPION, H.G.—TWISTED FIBRE IN TREES

Plate I



1. *Terminalia tomentosa* Bedd., showing pronounced left handed twist, a healed lightning blaze following the course of the fibre. Naghan, Haldwani division, U. P.

2. An extreme case of left-handed twist. Dinapani, C. Almora division, U. P.

3. The bulbous base of a strongly left handed twisted tree

4. A dead tree showing left handed twist [illegible]

INDIAN FOREST RECORDS

Vol. XI. 1924 Part II

CONTRIBUTIONS TOWARDS A KNOWLEDGE OF TWISTED FIBRE IN TREES.

I. THE PHENOMENON OF TWISTED FIBRE WITH SPECIAL REFERENCE TO *PINUS LONGIFOLIA* ROXB.

1. Description of the phenomenon.

(a) GENERAL.

The occurrence of scattered examples of trees in which the woody tissue elements follow a more or less even spiral course up the stem instead of the normal vertical arrangement, has been noted and mentioned by writers on botanical and forestry subjects from quite early times, and the phenomenon is shortly touched upon by the authors or compilers of most of the standard text books.* (DEBARY,[1] 1877, p. 471 : HARTIG,[2] 1888 : K. GAYER,[3] 1888 : SCHLICH,[7] 1896 : NISBET,[5] 1905, etc.)

The basis of these accounts is almost entirely the work of A. BRAUN[9] whose attention was apparently directed to the subject by an article by L. VON BUCH in DeCandolle's "*Organographie*" in 1827. Von Buch had noticed among other points that the direction of the spiral is usually constant in a given species, and is in opposite directions in *Castanea* and *Æsculus*. Writers in the following decades looked upon the phenomenon as a disease due to inadequate root development and thought the spiral always followed the sun, *i.e.*, was left-handed for the Northern hemisphere. VON TRUCHSESS,[12] a forest officer, recorded in 1840 a report made to him from Arzberg and Waldsassen,

* Twisted or spiral fibre is known in German as *Drehwuchs*, or in older writings as *Drehsucht*.

that there were to be seen in these places whole crops of twisted pines, both on loam and granite, and on all aspects, whilst in other crops, straight and twisted trees were mixed together; the direction of the twist was always left, and seed from such trees also grew up twisted. WICHURA[13] in 1852 could only record the defect in three kinds of trees—*Castanea Vesca*, *Populus pyramidalis*, and *Pinus sylvestris*. BRAUN collected data from the gardens and parks of Berlin, Paris and Karlsruhe, and was in correspondence on the subject with Engelman in N. America, and with a brother in Spain. He would appear to have studied the phenomenon mostly in small twigs which could be examined with a pen-knife, supplemented by the external appearance of such large trees as were to be seen in the towns, and by countings among barked hop-poles. He recorded the actual angle of the spiral, the size or age of the specimen, and often the angle at different ages. Altogether he examined 167 species, finding appreciable twist in no less than 111 of them. He found some support for the view that twist is more frequent in isolated trees than in crops, and satisfied himself that, especially in *Pinus*, the shorter the internode the more intense the twist. He shewed that the angle may increase with age as in *Punica*, or decrease and finally change over in *Pinus* and *Picea*. Among thousands of *Aesculus*, he never found a left-handed twist, whilst on the contrary, *Populus pyramidalis*, when twisted was equally constantly left-handed. *Pyrus communis* was almost always right-handed and *Salix alba* left-handed with rare exceptions, whilst *Carpinus* though most often R,† is almost as often L. As for twining plants, so also for twisted fibre in trees, L spirals are most frequent, *e.g.*, of the indigenous species examined, 34 are R to 15 L. In a given genus or order constancy is the rule, thus all the *Abietineae* and *Salicaceae* are, at least at first, L, whilst *Cupressineae* and *Leguminosae* are R. In some cases there seems to be a difference of direction in different localities, but verification is needed: an example quoted is that of *Liriodendron* in America (L), and in Europe (R). One of the most important of Braun's contributions was the firm establishment of the fact that a change in the direction of the spiral with age is quite usual: *Pinus*, *Picea*, *Abies*, *Tilia* and *Amelanchier* were all found to be L in youth changing to R later in life—no satisfactory case of the opposite possibility being found. WICHURA[13] had already found that about 1 per cent. of some pine poles 1″—3″ in diameter were L twisted with none

† Throughout this paper, the accepted mechanical conception of right and left-handed spirals is adopted as in general use for screws. Some of the older writers including Braun use them in the opposite sense as was customary in Military manœuvres. A right-handed twist will here be designated with "R" and a left-handed one with "L" and in an R tree, the spiral will appear to cross towards the right in ascending.

R, whereas in larger trees the forms were about equally common. BRAUN,[9] in the Rhine hopfields, on 2″– 3″ diameter poles (20-36 years old), found only 5 out of some 150 were truly straight, 1 had a slight R twist and the rest were all L, usually at an angle of 4°- 5°, rarely up to 10°. He also says he could detect the twist even in one year old shoots. COOK[39] (Figs. 180, 181) gives good photographs of R and L mature *Castanea Vesca*, and of an R twisted beech at Kew.

Twisted fibre is most frequently met with in *Aesculus*, *Castanea*, *Quercus*, *Acer platanoides*, *Tilia grandiflora*, *Carpinus*, and *Populus pyramidalis*, among N. European deciduous trees, and in *Pinus sylvestris* among conifers. It is frequent in *Juglans*, *Betula alba* and *Pyrus communis*, whilst no records have been found of its occurrence in *Fraxinus excelsior* and *Pinus Cembra*. As regards intensity in the individual, Braun found *Punica Granatum* with angles up to 45° to head the list, followed by *Syringa vulgaris*, up to 30°. Gayer notes that in *Pinus sylvestris*, the spiral may twist completely round the bole of a tree in a height of 5′—7′, *i.e.*, at an angle of about 55°, but these angles are far exceeded by *Pinus longifolia* in which complete horizontality or 90° is not rarely reached. Numerical data for frequency are given below (p. 13).

In America, ENGELMAN[6] found twist commonly in *Juniperus virginiana* (R), *Pinus Strobus* (53 cases of L to 1 of R), *P. ponderosa* (55 R to 2 L, possibly among big old trees), *Liriodendron* (L), and *Robinia* (R). On the Pacific side, *Picea sitchensis*, *Pseudotsuga Douglasii*, *Thuja occidentalis* and *Pinus monticola* are all reported to be affected, the first mentioned freely (up to 25 per cent. of the crop in Canada), and the last rarely. Recently McCARTHY[14] has made a special study of the phenomenon in *Picea rubra*, his " Adirondack spruce," in which species it is of very common occurrence in the Adirondack Mts.; he finds that just as in *Pinus sylvestris*, young trees are mainly L, and the older trees R, the change being associated with a change in the rate of growth. Another note from Canada is to the effect that—" Almost all trees (of *Picea sitchensis*) standing out of the perpendicular shew twisted grain."

In India, twisted fibre can similarly be met with in a great variety of species, though some such as *Bombax malabaricum* never seem to develop it. TROUP[17] mentions *Hardwickia binata*, *Populus euphratica*, *Boswellia serrata*, *Casuarina equisetifolia* as particularly liable to twist, and *Terminalia tomentosa* (Fig. 1), *Eugenia Jambolana* (R) and *Garuga pinnata* (R) might well be added as equally so. Of the associates of *Pinus longifolia*, *Pieris ovalifolia* very frequently, and *Rhododendron arboreum* and *Acer oblongum* not rarely, are found with the defect, which

also occurs occasionally in most of the other species. Among the conifers, scattered examples may be seen in blue pine, deodar and silver fir, but records for the direction of the spiral are not available except in the case of the blue pine, *Pinus excelsa*, for which OSMASTON[15] records both R and L, expressing a doubt as to whether R is any more common in old trees than in young ones.

The complex case in which the fibres of successive circumferential layers of wood shew frequent and pronounced changes of direction, as exemplified by *Shorea robusta*, is frequently observed, but is a different phenomenon altogether, more nearly comparable with the more generally quoted case of *Guaiacum* where obliquity is said to be found freely in radial planes as well as tangential, with undulations often reaching 45° each way.

Finally, it may be noted that according to GOPPERT[7] twisted fibre has been detected in the wood of fossil conifers.

Attention is directed to the affected trees by the oblique direction of the fissures in the bark (*Quercus*, *Castanea*, *Terminalia tomentosa*, Fig 1, *Populus*, *Juniperus*, etc.), or of the slight ridges and depressions on the surface of the bole, especially in smooth-barked species (*Carpinus*, *Fagus*), or again where the bark is freely scaled, by striations on the bark (*Pinus longifolia*, Fig. 3, and other pines). In most conifers, and many broad leaved trees (*Alnus*), the defect only becomes apparent when the bark is removed. Lightning, which has itself been adduced as causing twist (*e.g.*, by Cohn), often reveals the occurrence of twisted fibre as its splintering and splitting effect usually follows the direction of the fibres (*cf.* Fig. 1).

The available information reviewed above may be summarised as follows :—

(1) Spirally twisted fibre is of frequent occurrence, varying between very wide limits in its incidence in different species but liable to occur in practically all.

(2) The inclination of the fibre varies considerably in different species, with a wide range within the species, but some exhibit a much greater degree than others.

(3) The direction of the spiral is very usually constant in a given species at a given age, but the degree of constancy varies with the species. Allied species and genera usually behave similarly.

(4) Right handed twist strongly predominates as the final condition.

(5) It is common, especially among conifers, for the tree to be left-handed in early life changing to right-handed later on; the converse case has never been recorded.

(6) Right-handed twist may increase in severity in the individual with age (*Punica*).

(7) In Europe and Asia at least, *Pinus* develops twist much more frequently and intensely than *Picea* and *Abies*.

(8) In *Pinus*, twist tends to be more intense when left-handed than when right-handed.

TWIST IN SHELLS.

It is permissible to refer here to the comparable phenomena in animals particularly as they have long been the subject of special study in the Mollusca. COOK[39] has collected the available data for shells (and indeed all other animate and inanimate objects), and a few selected examples may be quoted. In the common whelk (loc. cit. p. 48 and figs. 182,183), only one case of a left-handedshell occurs in a hundred, though the fossil shells which may be found in the same locality, as at Felixstowe, are at least as constantly left-handed In another case (*Laniatcs*, p. 156), the shells are all L in one locality and R in another, whilst in *Tornatina* (loc. cit. p. 158) the spiral changes from L in the embryonic form to R in the adult - a case especially interesting in comparison with twist in trees. Another peculiarity (p. 159) is the numerous cases in which the shell is sinistral but the animal dextral, the converse case being also known.

(*b*) PINUS LONGIFOLIA.

TROUP[16] has collected the information available on the occurrence of twisted fibre in *Pinus longifolia*. CANNING and SMYTHIES have made the most important contributions. Emphasis is correctly laid on the fundamental difference between right and left handed twist but the earlier literature on the subject has not apparently been consulted. The existence of twisted fibre can commonly be recognised on standing trees which have reached the age for the production of scaly bark by the striations on the bark flakes (Figs. 3 and 4). These striations coincide with the long axis of the cells and they may also be accepted as shewing the direction of the axis of the cambial cells *at the time the layer of bark visible was laid down by the cambium* - the latter being an important proviso as will be seen later. The dead snags of branches so common in the crowns of large trees also give useful indications as to the course of the woody tissues, as it is usually easily visible in them. Lightning-struck trees and fallen logs from which the bark has been removed by decay or otherwise, reveal at a glance the direction of the fibres, and any changes of direction there may be at different heights of the bole

can be noted and measured (Figs. 4 and 8). Old logs in an advanced stage of decay, or better still, logs partially burnt through, reveal what changes of direction of fibre have taken place during successive periods of the tree's life (Figs. 5—7).

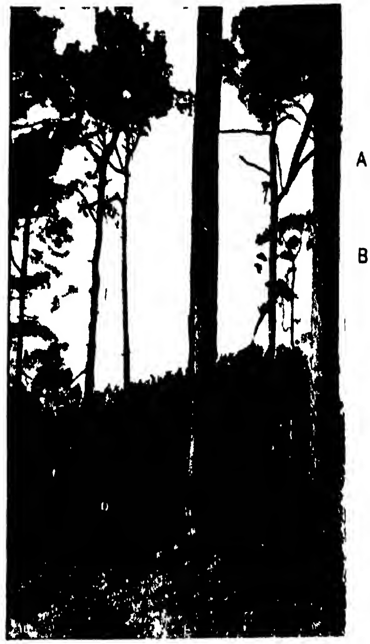
LEFT-HANDED TWIST.

Left-handed twist is found to be by far the most frequent type ; it occurs in trees of all ages from small seedlings to big overmature stems ; it commonly exceeds the other form in intensity and may even reach horizontality in the basal part of a tree (*cf.* Figs. 7 and 13). In some extreme cases, the whole outer surface of the bole assumes a corrugated appearance with raised spiral ridges (Fig. 2). A detailed description of its occurrence and appearance in the seedling will be given in Part II, and it will suffice here to mention that the twist is usually most pronounced in the hypocotyledonary region [Figs. 28 (1) and (3)] extending some 2″ down from the insertion of the cotyledons : this region is ordinarily above ground and is often enveloped in a thick green and spongy cortex. The spiral generally straightens out rapidly in the roots [Fig. 28 (3)] but is usually continued for a varying distance upwards into the stem, though practically never right to the tip [Fig. 28 (10)]. The spongy cortical development mentioned, giving the appearance of a carrot, is also continued a few inches upwards from the cotyledons. The course of the fibres between the insertion of the cotyledons and the whorl of buds $\frac{1}{20}''$ to $\frac{1}{10}''$ above them, is liable to be irregular, but an abrupt change of angle at either of these points is frequently found a decrease in the stem as compared with the hypocotyl being the general rule [Fig. 28 (2)], though the converse also occurs [Fig. 28 (17)]. The twist may be so intense that 3 complete spirals are completed in a length of 4″ [Fig. 28 (18)] above the cotyledons, or a spiral in less than an inch below them [Fig. 28 (3)].

Intense twist in larger trees is commonly associated with a swollen bulbous base (Fig. 3).

L-twist is further to be found in trees of all qualities including the best, but is more particularly frequent and intense in inferior or stunted growth. With minor exceptions, the intensity of the twist is greatest at the base of the stem, especially where this shews the bulbous swelling mentioned (Fig. 4), and diminishes upwards, sometimes rather abruptly just above the swelling, but more often gradually. Seedlings also exemplify this latter feature very well [Fig. 28 (5)]. Data selected at random for four trees will serve to illustrate the variation which may occur in the individual, and the fact that the

An old stump partly rotted away shewing left-handed [tw]ist of 85° over left-handed twist of 20°. Maharpali.



6. A dead standing tree shewing 10° right-handed twist superimposed on straight fibre at A, and slight left-handed twist at B. Park[illegible]t, C. Almora division

[illegible] rotted and burnt log shewing 50° left-handed twist over left-handed twist. Maharpali, C. Almora division.

8. A drifted log shewing [illegible] right handed twist. Tanakpur, Haldwani division.

foregoing remarks are generalisations to which exceptions are readily found. None of these four trees had a swollen base.

Age. Years.	Girth at Breast Height.		Height.	Angle of fibres to the vertical, in degrees, at a height of —										
	ft.	ins.	ft.	5′	15′	25′	35′	45′	55′	65′	75′	85′	95′	Average.
215	8	7	140	18	12	17	22	15	20	22	20	15	15	17·6
227	7	6	—	10	6	9	12	8	10	8	7	5	7	8·2
227	7	11	112	10	0	5	—3	0	3	2	6	0	7	3·0
220	6	3	122	0	5	0	0	1	0	10	2	7	18	4·3

For *Pinus excelsa*, OSMASTON[15] (p. 13) notes that the intensity of L-twist seems not to increase downwards but to reach its maximum about the middle of the bole.

The variation in the degree of development of twist during a tree's lifetime is at once less easily observed and more complex. The seedling period is being separately dealt with, but the data collected indicate clearly enough that twisted fibre is altogether exceptional in plants only one season old, but may appear suddenly with considerable intensity in the wood formed in the second season ; there are also indications that there may be an increase in intensity in following years. Data for young poles are scanty, but the indications are that with plants growing under adverse conditions (especially when subjected to hacking and lopping), there is a tendency for the angle of the fibre to diverge further and further from the vertical, whilst on the other hand, under favourable conditions, the reverse possibly also occurs. In older trees there appear to be at least two possibilities. Where a swollen base is developed (and perhaps in other trees growing with swollen based ones), the twist commonly becomes more and more intense till the limiting condition of horizontality of the fibres is reached (*cf.* Fig. 6). Elsewhere, perhaps most pronouncedly in good localities where the trees reach large dimensions, as the tree passes from maturity to overmaturity, a definite diminution of the angle the fibres make to the vertical sets in, and may progress until verticality is once more reached, or even overstepped, when a right-handed spiral becomes apparent. (Fig. 7 illustrates a rather unusual such case where a twist of 78° L has diminished with time to 50° L.) This change agrees with what has been found for other species by Braun and others, with the difference that it only sets in for *Pinus longifolia* late in life, say not before 150 years of age, whereas the change occurs in *P. sylvestris* and *P. montana* at a diameter of about 6″, in *Picea excelsa* already at about 10 years of age, and in *P. rubra* at a diameter of 6″. The change is evidently most simply regarded

as the effect of a superimposed right-handed twist and as such is dealt with later. It is during this stage that the indications of the bark-striation will not agree with those of the outermost layers of wood, nor the latter with the condition of the bole as a whole. This variation with age may also frequently be recognised on the two tangentially cut surfaces of a sawn scantling. (Fig. 15 A and B.).

RIGHT-HANDED TWIST.

Right-handed twist is, as already mentioned, less frequently met with than the opposite case, but is very probably commoner than is generally recognised, especially in virgin forests containing a large proportion of overmature trees (Figs. 6 and 9). The type is virtually confined to large mature and overmature trees, and is to be expected in the usually good class of locality producing crops of such trees (SMYTHIES[21] p. 11). The twist is almost invariably found to be restricted to the outer layers of wood, becoming more intense centrifugally (as in *Punica*), the inner core being straight, or sometimes with a left-handed twist (cf. *supra* and Fig. 6) ; no case has been noted of any pronounced swelling of the base of the bole. CANNING[19] and LAMBERT (*in litt.*) record that in their experience in E. Almora, the degree of twist becomes more intense upwards in the bole, but this tendency appears to be less pronounced than is the converse for left-handed twist ; in fact, although this increased twist may be accepted as the general rule, especially well up in the crown of the tree, figures similar to those quoted above for left-handed trees are most frequent.

In the few cases met with of a right-handed twist in young poles, the inclination of the fibres is very slight and only apparent over certain portions of the stem. Although earlier observations on 2746 two-year old seedlings indicated an almost complete absence of right-handed twist at this stage, some 4-year old plants have been found shewing this form of abnormality 34 definitely, and 62 slightly out of 1387 examined [cf. Fig. 28 (13) (22-24)]. These figures correspond to 0 per cent. for the 2-year-olds, and 0·2 per cent. or 0·4 per cent. for the 4-year-olds from the same sowings. Right-handed twist has not been found in young natural coppice shoots with the exception of one lot mentioned on p. 26 and illustrated in Fig. 11 ; here however it was quite pronounced.

A connection may perhaps be recognised between the absence of right-handed twist in the young tree with active height growth, and its tendency to put in an appearance in old trees in which height growth has virtually ceased (Canning), and to reach its maximum expression in the

A dead standing tree showing right-handed twist. [illegible] S. C. Almora division.

9a. The lower part of the bole of the same tree with 10° right-handed twist.

10. A typical strongly left-handed twisted seedling, Dehra Dun sowing 28, 4 seasons old. [illegible] L = "2t"

upper parts of the boles of the same. Osmaston was unable to recognise any definite increase upwards for R-twist in the case of *P. excelsa.*

(c) MICROSCOPICAL EXAMINATION.

Some account is required of such further light as can be thrown on the phenomenon by a more detailed examination of the normal and twisted tissues. Our pioneer worker, BRAUN,[10] strongly emphasised the fundamental difference between the phenomenon now under discussion, and all other cases of so-called "torsion" found in twining plants and of tissues actively growing in length, of which also he had made a special study. He pointed out that in the tree, the axis as a whole is not twisted, but only certain layers of it and also shewed that a twist in the underlying fibre does not affect the spiral arrangement of the leaves on the shoot. In testing his hypothesis that twist is caused by the longitudinal growth of the tissue elements on an axis of fixed length, BRAUN, despite difficulties of technique, satisfied himself that the cambial cells in *Æsculus* increase at least 50 per cent. in length during differentiation, the ends becoming tapering and pushing their way upwards and downwards among their neighbours. He drew diagrams illustrating this [which reappear in STEVENS'[22] and STRASBURGER'S[23] compilations], and shewing that if the cells always push to the same side of the neighbouring cell next above, the nett effect is uniform inclination of the long axis of the fibres resulting on differentiation (Fig. 18). The conifer is theoretically obviously the simplest case, and it can easily be seen (Fig. 19) that the ends of the tracheids are wedge shaped, being pointed as viewed in tangential section but broad in radial section; but uniformity in the relative position of the tapering ends cannot be traced, perhaps owing again to technical difficulties, the chief of which are the great length of the tracheids and their initials and the greater extent of the sliding growth.

In the case of *Punica*, Braun found that where the ends of the fibres were very oblique, their orientation agreed with that of the fibres as a whole, but not where the obliquity was less pronounced. It is not easy to determine the extent of the elongation during maturation : he thought a 33 per cent. increase probable for *P. sylvestris*, but as the tracheids may be even 4 mm. long, it would appear that it may be much greater -- it must take place rapidly as the bordered pits which must correspond on adjoining tracheids are very soon defined. On the other hand, STRASBURGER states that there is hardly any such increase in length in pine tracheids which retain much the same shape as the

cambium cells from which they originate. The cambium cells in *Pinus sylvestris* as viewed in tangential section are seen to possess an elongated hexagonal or parallelogrammic shape with the long axis vertical: average dimensions are $15\mu \times 20\mu \times 2{,}000\mu$.

LOREY[27] p. 222, categorically states that such a unidirectional course in the tracheids and fibres during their sliding growth is the cause of twisted fibre, but it is evident, as Braun fully realised, that in itself this is at best a very partial explanation, inadequate to account for more than about 3° of twist, and will be discussed later. Perhaps because they had not extreme cases of twist before them, the earlier workers apparently did not realise that the cambium cells themselves become strongly inclined, as is very clearly the case in *Pinus longifolia,* and probably in most or all cases especially where the intensity of the twist is strong and changeable.

A study of the distribution of the bordered pits on the tracheids of strongly twisted wood, and of the transpiration current through the same, on the lines described in detail by PENHALLOW,[24] HABERLANDT[25] and JEFFREY[26] would be of interest and value as probably giving indications as to whether the abnormality is a disadvantage to the tree possessing it. The phlœm tissues being equally inclined, it would be interesting to look into the distribution of sieve plates in the sievetubes, but no such investigations have yet been carried out.

2. Twisted Fibre in Relation to the Locality.

The widespread distribution of twisted fibre in trees has already been illustrated in the foregoing section, but it remains to discuss what effect the factors of the locality may have on its occurrence. Writers on forestry do not appear to have much to say on this point, though reference may be made to VON TRUCHSESS'[12] record mentioned on p. 1, and MATHEY[29] writes that " when the roots strike through a hard layer of soil into a softer, twist is usually produced."

HARTIG,[2] LOREY,[27] NISBET,[5] and others do not even mention it, but H. MAYR[28] (1909), writing that—" this much is certain that all species on dry soil, southern aspects and stony ground, tend to be twisted " voices the general opinion that the phenomenon is more frequent and apparent in unfavourable localities, althoughstriking exceptions can very frequently be found under what are apparently optimum conditions of growth. Again the Director of Forestry, Ottawa, Canada, writes that in Canada " the concensus of opinion is that twisting is a habit of growth due to local conditions.

In India for *Pinus longifolia,* HEARLE [30] in 1898 noted that "it would seem as if this curious phenomenon was due to poverty of soil, lowness

of altitude and unfavourable aspects combined." TROUP[16] (p. 41) describes the geographical distribution of twisted fibre for *Pinus longifolia* as far as known to him, and it may be summarised to the effect that it occurs throughout the range of the species in a varying but generally small proportion, and is intensely developed in the Central Kumaon hills where the present writer has collected most of his information. GRESWELL (*in litt.*) says that in the Punjab depots, the majority of *chir* timber has twisted grain. SMYTHIES (*in litt.*) notes that planted trees in Calcutta Botanical gardens shew very intense twist ; it is the same at Delhi, and sowings in Dehra Dun, where also the tree is not indigenous, have given more twisted stems than are obtained with the same lot of seed sown in Kumaon : in these cases, soil conditions were undoubtedly favourable to tree growth but the climatic conditions were not those natural to the species. It remains to enquire what local factors prevalent in Central Kumaon are causatively connected with this maximum development.

As regards the distribution of right-handed twist very little information is available, and TROUP's[16] (pp. 39, 41) cautious generalisations require modification. As already stated, it reaches maximum development in eastern Kumaon and very probably the adjoining parts of Nepal, and probably only here reaches economic importance, but 5 per cent. to 10 per cent. of the total crop is not infrequent in western Kumaon and scattered trees can be found not rarely in Naini tal, Chakrata and probably most other forest divisions. The point to be emphasised is that right-handed twist in *Pinus longifolia* is a phenomenon of old age, and is accordingly not to be expected except where trees of at least 150 years of age are common the East Almora trees affected probably average some 200 or more years of age.

The investigator's attention is early attracted towards a probable connection between the proportion of twisted trees in a forest area and the proximity of villages and the pressure of the population on the forest (*cf.* TROUP,[16] p. 21). This is at once apparent in any block of forests shewing twist. *e.g.*, Airadeo, and is well brought out by some figures quoted in the working plan for the Central Almora forest division which has been closely examined in this connection, (CHAMPION[31]). Areas in which less than 30 per cent. of the growing stock is straight fibred were recorded and mapped as twisted, and if the figures for the five ranges are taken, it is found that the fractions of the total areas recorded as twisted bear a very close relationship to the density of the population. The figures vary from 79 per cent. for the range including Almora town (*cf.* Fig. 12) down to 4 per cent. for the very thinly populated Kapkot range. Apparent exceptions can be quoted from

C

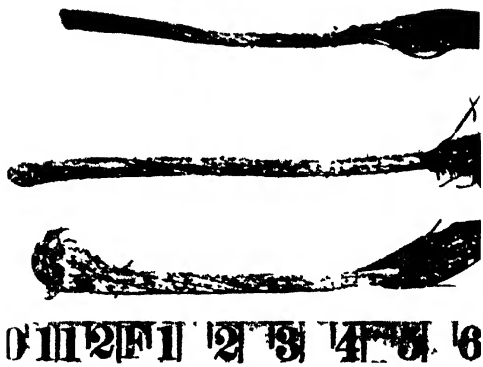
Almora district, *e.g.*, unexpectedly straight forests in Kaligadh near Ranikhet and in Jaikhal in Pali, whilst it must be remembered that similarly intense pressure in other parts of the range of the species, has not produced this result.

A good deal has been written on the connection between the prevalence of twisted fibre and the underlying rock. The data available may be summed up to the effect that twist is exceptional on recent stratified rocks, and on quartzite, and is more prevalent on mica schist than on other formations, but it must be emphasised that these are but wide generalisations to which well marked exceptions are frequently met with. SMYTHIES[20] has paid special attention to this aspect of the question and finds that (in Kumaon) the tertiary sandstones are practically free from twist, the quartzites and dolomites comparatively so, the granites and gneiss fairly free, whilst mica schists are essentially the home of twisted fibre. OSMASTON[15] records that in Garhwal, L twist is of very rare occurrence on limestone : in Almora though not actually rare, it is at least relatively infrequent on this rock. In Kangra, twist is fairly common on both gneiss and mica schist, but in the Siran forests of Hazara, patches of schist in gneiss are accompanied by considerable development of twist rare on the gneiss itself. In Mandi State, there is an interesting contrast between the straight fibred forests on quartzite and the twist on schists. Near Rawalpindi, it is as in Kumaon rare on sandstone rock. On the other hand the forests on typical mica schist near Ranikhet are remarkably free from twist (Kaligadh and Jagdeo) whilst others on granitic gneiss (Tambadhaun, Karchuli, Ukhallekh) are intensely twisted; in Sarna block of Central Almora division, intense twist occurs on dolomitic limestone, as also on pink granite in parts of Bhatkot. It does however appear to be general that twisted fibre is rare on the tertiary formations.

Of the other fixed factors of the locality, the opinion in Europe that twisted fibre is most frequently met with in unfavourable localities has already been quoted (p. 10).

SMYTHIES[20] says for *chir* that " southern and western aspects are usually more twisty than northern and eastern aspects," and that "altitude has apparently little to do with it except in so far that lower altitudes are often nearer villages." So many factors are involved that even if it be admitted that northern slopes are better than southern, it is not permissible to find the reason in the difference of aspect, and on present information, a non-committal attitude is preferable.

MATHEY'S remark that " the larger and more vigorous the tree, the more pronounced is the twist," is worth mention.



11 Two season old coppice shoots with bark removed showing 9—18 right handed twist Almora [illegible] Ranikhet division

12. 100% left handed twisted forest. Garanath, (Almora division

13. An extreme case of left-handed twist accompanied by contortion.

3. The Commercial Significance of Twisted Fibre.

Both in the forest and the mill, timber with twisted fibre is liable to be more difficult to saw than straight grained timber, but this is a small matter compared with the great inferiority of the sawn produce (TROUP,[17] SCHLICH[7]). Although a minor amount of twist is not of any serious consequence when the stem is used in the round or merely squared (*e.g.*, in masts of *Picea excelsa* where a right-handed spiral is often seen), the resultant loss of strength of sawn timber under tension or compression and especially lateral displacement or torsion is so serious as to become a matter of the highest economic importance. Brief consideration of the distribution of the twist radially in the log will make it clear that in any scantling cut from the peripheral portions, the 'grain' along which the wood will readily split, may cross completely from one side to the opposite side and a very slight shock or strain suffices to break the piece into two. Very often, especially with hand-sawn sleepers sawn through the core, the checks will reveal a twist on the outer flat surface but little on the inner : within reasonable limits such sleepers are serviceable (Figs. 15 16). A very striking case for railway sleepers is quoted by SMYTHIES, where, of a consignment of sleepers sawn from selected apparently good trees, no less than 10 per cent. broke across in seasoning (Fig. 17) and 75 per cent. would have been rejected for antiseptic treatment. Of the whole area under *chir* of Central Almora division, 38 per cent. is estimated as having over 50 per cent. of the trees twisted beyond the 7° accepted in railway ties apart from the vast number of stems affected in the remaining 62 per cent. ; probably 50 per cent. of the whole growing stock is a fair approximation (*cf.* Fig. 12). OSMASTON estimates that in the N. Garhwal division, 2 per cent. of the total crop is unfit for sawing, but he takes the limit at 15° which is high. For *Pinus excelsa* in the Nandagini valley, he estimates that half the crop is more or less twisted, but scarcely 1 per cent. so severely as to be unfit for sawing. Similarly for the Adirondack spruce McCARTHY[14] found 48 per cent. of the 2,372 trees examined by him failed to pass the airplane specification of 1 in 20, or 3°.

Numerical data for frequency are few. GAYER cites the case of a *Pinus sylvestris* forest near Trier where 84 per cent. of the trees have twisted fibre and that similar cases occur in the Bavarian Alps, in Saxony, Switzerland and in the Forstamt Markt-läuten.

A very large proportion of the Sitka spruce and less of the douglas fir and cedar tested in Canada for airplane work was also found to be useless on this account, as already stated above. A degree of twist insufficient to cause the total rejection of the piece of timber, is still enough to depreciate very considerably its value, for the irregular warping which

occurs on seasoning is a very troublesom e defect ony too apparent in buildings and furniture constructed from such material. Twisted trees in the forest are specially liable to snowbreak and to damage in fellings owing to their lack of strength under tension or bending strains.

It is very difficult to square twisted logs with the axe, and impossible to prepare split and axed planks, or split palings, staves and shingles; *planing is also difficult. In many districts in Germany, coopers are said to express a preference for L to R material for their staves, but the basis for this prejudice is not known* (GAYER[3]). In the intensely twisted *Pinus longifolia* areas near Almora, many logs or parts of logs cannot even be split up into fuel and can only be converted into charcoal; moreover where fuel billets can be split, they are of inconvenient shape for stacking, handling and floating.

Another use for which a certain degree of twist is not a defect is for wooden rollers such as are made out of sycamore (NISBET[5]).

4. The Question of Inheritance of Twisted Fibre.

As this problem is being made the subject of Part II of this paper, but little detail is required here. HARTIG[2] suggested that one ought probably to distinguish between an inherited and an acquired twist. MAYR[24] writes that "it is always asserted that twist is heritable, but nowhere has a satisfactory investigation been made on the point." MATHEY[29] was of opinion that it appears hereditary in certain forests such as those of St. Amand and Marchiennes, but is usually fortuitous and sporadic. TOUMEY[32] (1916) records a small experiment with seed from a twisted *Pinus Jeffreyi* for which in 3½ per cent. of the 750 seedlings obtained "a well marked twist was evident below the cotyledons." The opinion in Canada is that twist is not an inherited defect (Director of Forestry, Ottawa, *in litt.*). SMYTHIES has twice raised *Pinus longifolia* seedlings from seed from twisted trees without finding any appreciable twist in the seedlings (this is commented on later, p. 32), whilst TROUP[18] did find twist in seedlings of similar origin grown in Dehra Dun in 1912. CANNING[19] (p. 116) has recorded a case of a right-handed twisted overcrop with left-handed twisted regeneration, conditions being unfavourable to the seedlings. TROUP[16] (p. 45) records his final decision that twist is not inherent in the seed.

The interesting cases of the Almora plantations and the Kausani Estate (in Almora district) are noteworthy in this connection and are liscussed in part II (pp. 34, 35), but here also the evidence is conflicting, he former supporting the existence of heredity and the latter being ›pposed to it.

14. The stump of a badly shaped strongly left-handed twisted tree after removal of the bark. Maharpali.

15 Sawn timber shewing twisted fibre. Barmdeo Boom, R. Sarda
A Strong right-handed twist in the top piece, strong left-handed twist in the second, and moderate right-handed twist in the fourth

B. The same timber with the top two pieces turned round
Note that the top piece now appears straight-fibred, having been sawn from a log with the usual straight fibred inner core with right-handed twist

With the object of obtaining some more reliable information on this important question, experiments on a fairly large scale, with seed of known and varied origin sown under varying conditions, followed by varied treatment of the resultant seedlings, have been carried out by the writer in Kumaon since 1916 and are described in Part II. The investigation is of course still far from complete, but the general deduction from the examination of large numbers of seedlings, coupled with general observations in the existing crops, is that a tendency to the development of twisted fibre is definitely hereditary in seed obtained from the badly L. twisted trees of C. Kumaon. This tendency does not find expression during the first growing season, but twisted fibre is freely found in the seedlings in the second and following seasons. HARTIG's suggestion that inherited and acquired twist should be distinguished receives some substantiation, and it appears that in most of its range, *Pinus longifolia*, like almost every other tree species, occasionally produces a twisted tree whose condition must be ascribed to "fluctuating variation" or some not yet understood reaction to the factors of the locality, whilst in Kumaon, from whatever cause, a local variety, freely intercrossing with the normal form, has originated, in whose hereditary constitution is a factor causing or allowing easy development of twisted fibre. It will be noted that this confirms MATHEY's belief already quoted.

There is no question but that selection by man acting by the elimination of the straighter stems, must have played an important part in bringing about the condition now found; this point must be emphasised as an essential part of the explanation offered of the facts as one finds them in the Kumaon pine forests.

It is suggested that just as many familiar varietal forms (*e.g.*, melanism, peloria, fastigiate stems, etc.) are common to numerous species, so also this character of tendency to produce twisted fibre may be developed locally in species other than *Pinus longifolia* (*e.g.*, probably in *Picea sitchensis* and *Pinus Jeffreyi*). The case is however much complicated by the perennial habit of the trees and the indeterminate crossings which take place, since the pollen parents of no two seeds in a given cone are necessarily the same.

5. The Possible Causes of Twisted Fibre.

(*a*) GENERAL THEORETICAL DISCUSSION.

The occurrence of spiral form is so commonplace (COOK[39]) as hardly to require mention, in fact one is almost tempted to treat it as the normal condition and look for reasons to account for growth in straight lines. Moreover GAYER[4] gives as his experience with wood, that "the rule is rather a more or less drawn out screw like twist of the wood

fibres," than for the latter to follow a straight course parallel to the tree axis. It is usually the result of unequal rates of growth in different parts of the organ affected, either the more rapid growth in the peripheral parts than in the centre (SACHS) as in the orchid ovary, or inequalities on different parts of the periphery stimulated by unequal weighting about the axis (DE VRIES[37]) as in the case of most stems, petioles and similar organs. Many spirally twisted parts, especially those found in fruits are due to unequal contraction in different layers on dessication, *e.g.*, the valves of pods in legumes and *Impatiens* and the awns of many grasses. The fact that so many of these movements or displacements serve some function in the plant's economy, *e.g.*, assimilation, support, pollination, seed dispersal and so on, is to be considered as secondary since these end results can hardly account for the initiation of the phenomenon.

The origin of an inclination to the vertical of the long axis of the constituent cells of secondary tissues of a tree which bring about the appearance of twist, must be traced back to some influences, inherent or external, working on the differentiating cells of the secondary woody tissues and, in the case at least of more severe twist, on the cambium cells which by their growth and division, give rise to them. The directions in which the great growth activities of cambial cells can take place are very restricted : instead of being able to grow and divide equally in all directions as can a free swimming cell in a fluid medium, or to a less extent the cells of any young meristematic tissue, they are--considering any part of the bole of a tree virtually limited to an increase in an outward radial direction only, with an extremely restricted tangential expansion as the radius lengthens. Even growth radially involves the expenditure of considerable energy in rupturing and pushing outwards the phloem and cortical tissues already formed.

The particular orientation universally found among elongated cells of a stem with the long axis parallel to that of the stem as a whole, and so vertical, might possibly be due directly to geotropic response, or what seems more probable, to the drawing out of the differentiating cells under the influence of the rapid elongation during early growth at the very commencement of life of the part under consideration, such drawing out naturally conforming with the direction of elongation and so being in the case of the main axis of a tree vertical, *i.e.*, in the same position as positive or negative geotropism would constrain it to take. Thereafter by the relatively simple process of increase by divisions in the radial plane conforming with expansion in that direction, in the plane at right angles to this (tangential) and inthe pl ane at right-angles to the long axis, every daughter cell will come to be similarly orientated.

The fact that such orientation gives maximum efficiency in the resultant tissue for supporting or transmitting superimposed weight, is better considered as a consequence than a cause.

Starting from this basis, and considering the main stem only, inclination of the tissue units might result as follows : -

(i) Under special conditions, by a geotropic response in the cells.
(ii) By the introduction of a new internal force overcoming the tendency to follow the general rule.
(iii) By the action of an external force.

(i) *Geotropic Response.*

Of the three possibilities mentioned, the first can be shortly dismissed. At first sight, the observation quoted as from Canada, that leaning trees are specially liable to be twisted, suggests that geotropism is a factor of importance. A tendency of the fibres on the sides of an inclined tree to conform partially to the gravitational pull can often be observed but it is obvious that without various arbitrary provisions, geotropic response in the cambial cells could never give a continuous spiral up the axis.

With *Pinus longifolia*, leaning boles shew no unusual liability to be twisted and crops on steep slopes where almost every tree has a curved section at the base, present no special development of twist. However, the tendency of branches to be more intensely twisted may be borne in mind.

Again, the fastigiate and weeping varieties of many trees, and the more or less constant angle between stem and branch for a given species or the branches of an inflorescence (especially cymose forms), suggest that it is not impossible that a plant member may respond to geotropic stimulus (quite possibly as a resultant with a second force acting simultaneously on it) without orientating itself accurately in a plane coinciding with the lines of gravitational force. Here also however various unsupported assumptions are necessary to account for the phenomena described as occurring in twisted trees.

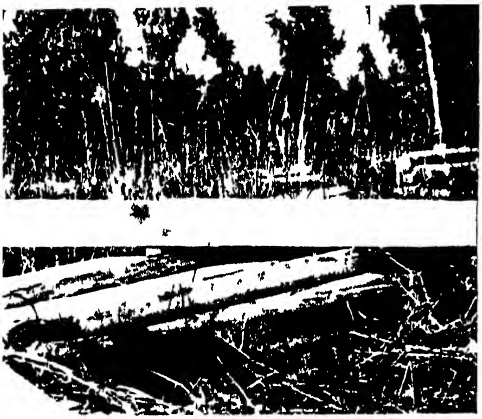
It has been seen that in the seedling, twisted fibre is most strongly and frequently developed in the hypocotyledonary zone including the transition from the positive geotropism of the root to the negative geotropism of the stem. This coincidence is noteworthy as indicating that after all, geotropism must always be borne in mind in this problem. Geotropic response is commonly manifested only in tissues growing in length, but it will be seen later that it is only the first small beginning of twist that is difficult to explain, and this might take place in the seedling.

(ii) *A new internal force.*

The second suggestion is that we may have to do with the introduction of a new internal force overcoming the tendency to follow the general rule of verticality.

There is the explanation already expressed in 1874 by SACHS[38] that the inclination of the cell axis is due to excessive longitudinal growth vigour of the cells divided off by cambium on the fixed bole, which can only be relieved in this way. In the case of the swollen base of the extreme left-handed twister, abnormally great radial expansion accompanies the twist, further supporting this idea of excessive growth vigour. It may further be possible to correlate with the last mentioned example, the fact already mentioned (numerical data being given in part II, *p. 51*), that in the seedling, considerable cortical "carrot" development [*Figs. 20 and 28(1)*] tends to be accompanied by twisted wood: most of the excess growth vigour finds vent to its activities on the cortical side of the cambium, but such wood as is laid down (the woody axis usually remains normally cylindrical in these cases) is affected as in the old tree. The data collected for 5 lots of 2-year-old seedlings totalling 1,941 individuals, support this supposition. Five stages in "carrot" formation were distinguished, but may for present purposes be condensed into two only, normal and strong. In every case there were between 25 and 35 per cent. more seedlings twisted in the strong carrot class than in the normal, the percentages for the whole number taken together being 52 and 19 respectively. Similar again is the strong development of twist in the swollen zone above the constriction of a girdled stem (*cf.* p. 50 and fig. 30).

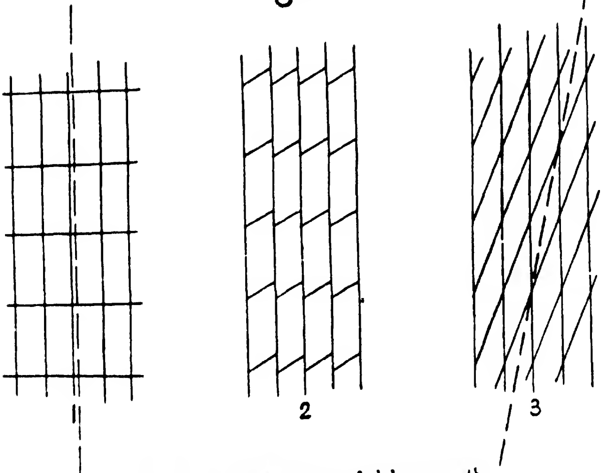
A further hypothesis which appears worth following up, is that this excessive growth vigour is due to a local check in the transport of food materials. It has been seen that the twist is most intensely developed at the foot of the tree in the left-handed twister where the woody axis enters the ground and hindrances to volume growth are met with; in a similar position in the seedling where the arrangement of tissue units of the stem change over into those of the root; and in branches where they are inserted into the main bole. Similar possibilities occur above the girdle in girdled stems, and perhaps also in the right-handed twister in the upper part of the bole where growth is more active (as is usually the case for old trees) than further down. It has been mentioned above that twist is especially frequent on mica schist, and the suggestion is that the structure of this rock is such as to render the development of a good normal root system particularly difficult; trees growing in narrow clefts of any kind of rock will be similarly at a disadvantage and in all countries have been noticed as especially liable to develop twist.



16 A scantling sawn from a bole with a narrow core of left handed twisted fibre at the centre, but straight outside. The section is slightly oblique to the pith which is included at the right hand end

17 Twisted railway sleepers broken in floating 4 are normal left handed samples and the fourth from the left was sawn from a log similar to that of Fig 16

Fig. 18.



Diagrammatic representation of sliding growth.

It may be objected that the root and crown development in a tree are too closely correlated to permit the formation in the crown of excess carbohydrate with the suggested local accumulation, but this precise correlation would equally require exact demonstration and does not appear to exist in the case of the girdled stem. Experiments made to throw light on the effect on the direction of the fibres subsequently laid down, of partial girdling and rigid circumferential binding of the stem of *Pinus longifolia* as a species particularly liable to twist both on young poles and on seedlings, are still in progress, but some results have been obtained and are quoted on pp. 50, 51. For the case of the seedling, the suggestion is made for what it is worth, that for a period, leaf development and carbon assimilation outstrip the ability of the plant to utilize the available food material in the normal way the monsoon conditions under which *Pinus longifolia* grows are distinctly abnormal for the genus and the resultant tensions in the differentiating cells find relief by taking on an inclined orientation.

The actual mode in which increase in length takes place is, as seen in section 1 (*c*) above, what is known as sliding growth. It will be realised on consideration that as far as the result is concerned, the inclination of the unit elements will take place equally whether they meet squarely end to end or fit into one another wedge fashion, provided, as is the case, the elongation involves real growth and not mere change in shape. In any case, sliding growth alone is obviously inadequate to explain the facts : there must be a further influence at work to cause uniformity in the direction relative to the adjoining cells above and below followed by the unit undergoing it, or if not uniformity, at least a preponderance in one direction. BRAUN, having satisfied himself that some 3 was the maximum inclination theoretically possible with the known shape and dimensional increase of differentiating tracheidal cells with sliding growth, could only, as we have seen, suggest slanting walls in the infrequent radial divisions of cambial cells to explain the more intense twist commonly found, but he appears to have overlooked the possibility of a back action of the lengthening and inclining young tracheid on the parent cambium cell.

(iii) *A new external force.*

The last alternative is the action of an external force stronger than the tendency to vertical orientation. As such may be quoted wind action on a one-sided crown which has commonly been cited as a cause of twisted fibre ; *e.g.*, HARTIG[2] ascribes to it a case he found of a larch which had grown straight for 50 years and then in the next 30 years had become twisted till the course of fibres were 35° from the

vertical. The possibility of such an origin of twisted fibre must be admitted for individual cases, but it is totally inadequate as a general explanation.

(*b*) SPIRALS IN TISSUE ELEMENTS : SLIDING GROWTH.

A further matter next requires consideration. Whichever if any of the above suggestions is correct as to the cause of the development of twisted fibre, the twist developed should be equally to the right and to the left unless there are further directive forces at work on the growing cells, and also ultimately on the actual cambial cells.*

In dealing with the microscopic examination of twisted wood, it was seen that if in their sliding growth the differentiating tracheids tend to push past their neighbours predominantly on the one hand or the other, a quite appreciable degree of twist might result, and so the question arises as to what directive forces may exist to produce such a tendency. As mentioned on page 15 a spiral course is so common in the products of vital activity as examined microscopically or seen on a larger scale (*cf.* COOK[39]) that it is usually taken for granted without any question as to its wherefore. The spiral vessels of the protoxylem elements of coniferous wood and the spiral thickening of the tracheids in some species (leaving other plants out of the question) are very familiar.

The spirals in trachea and tracheids are usually constant in direction and right-handed, but left-handed spirals occur, *e.g.*, in *Pinus sylvestris*. In *Berberis vulgaris*, the first formed are L. and the later R. whilst in *Cucurbita* (as with its tendrils) both directions may be followed in one unit. The secondary thickening has generally a spiral structure revealed in what is known as "striation" of the tracheid membrane (Fig. 19). KRIEG[34] has made a detailed study of this "striation" in coniferous wood, notably in *Pinus sylvestris*, in which it is already recognisable in tracheids next but 1 or 2 from the cambium. He found that the striation is *always a left-handed spiral* (loc. cit. p. 218) with pitch constant in a given cell (37°—18°), the inclination of the slits of the bordered pits, and the micellar rows (as deduced from polariscope examination) conforming to it.† The inclination generally decreases

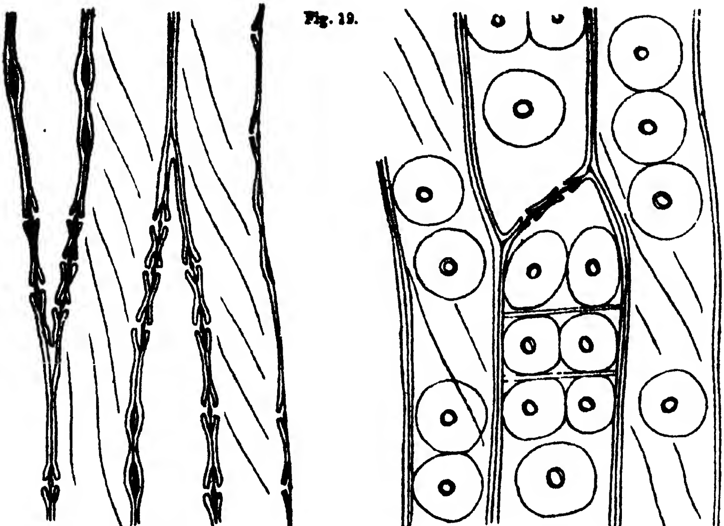
* In this connection the countings of the directions of the spirals in pine cones by E. G. GROOM (CHURCH[13]) are interesting. Instead of the 50 . 50 proportion to be expected, he found (cones all from one tree of each species).

P. laricio 1,100	70 L 30 R.
P. austriaca 1,600	46 L 54 R.

The well known case of the common whelk in which 1 L only is found to 99 R may be mentioned again.

† This is not always the case. PRIBALLOW[24] mentions *Pinus Strobus*, in the autumn wood of which the slits are parallel to the long axis of the tracheids: he considers this an advanced derivative from the normal.

Fig. 19.



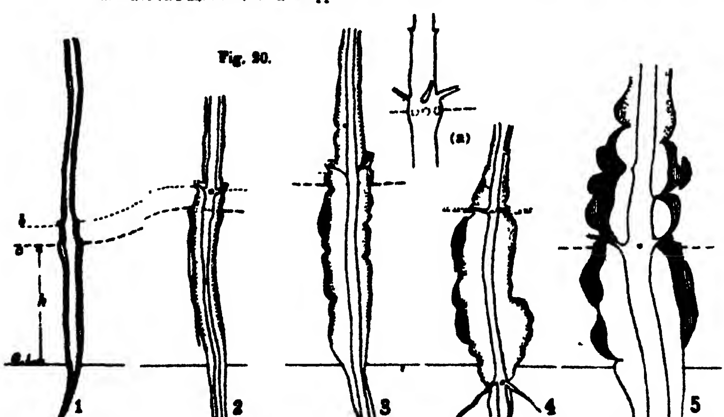
TANGENTIAL. RADIAL.

Tracheids in radial and tangential longitudinal section.

LONGITUDINAL SECTIONS OF RIGHT-HANDED TWISTED WOOD
ILLUSTRATING THE ENDS OF THE TRACHEIDS AND STRIATION OF THEIR WALLS.
×400 PARTIALLY DIAGRAMMATISED

NOTE.—In these sections, the tracheids are viewed from inside, the striation is therefore right handed, and not left-handed as at first appears.

Fig. 20.



Outline drawings of seedlings; from living plants: natural size foliage omitted; line shading indicating brown dead cortical tissues; stippling indicating green cortex.

G. L. = Ground Level.
c. = Cotyledonary insertions.
b. = Supercotyledonary wheel of buds.
h. = Hypocotyl.

1. 2-season-old seedling with no carrot development.
2. 2-season-old seedling with slight carrot development.
3. 2-season-old seedling with strong carrot development.
4. 3-season-old seedling with very strong carrot development.
(a) Enlargement of the woody axis at the insertion of the cotyledons.
5. 4-season old seedling.

with increasing diameter of the tracheid. PENHALLOW[21] (1907) makes similar observations and reproduces a fine microphotograph shewing how decay brings out the striation in the fossil wood of *Pseudotsuga miocena*. In spiral vessels, there is usually more than one spiral in each vessel, commonly 1-4 (up to 16-20 in Angiosperms). He makes out a good case for considering the spiral structure the primitive form for tracheids, all others being derived from it. *Cordaites* exhibit spiral vessels unusually well developed.

For *P. longifolia*, striation can usually be detected on some of the tracheid walls in any section (Fig. 19) without special treatment. In any one section the inclination is constantly right or left, but rare exceptions do occur. The slits of the bordered pits are mostly circular but when oval, the long axis is generally more inclined than the striation but in the same direction : the simple pits on the medulary ray cells are generally oval and obliquely orientated, and similarly conform in direction to the striation. Care has to be taken in this case to distinguish which side of the cell is being viewed.

DENHAM[40] (1922) finds a similar spiral structure in the cellulose wall of the cotton hair and even in the cuticle enveloping it. STRASBURGER[23] (1921) quotes the case of *Vinca*, the fibre-walls of which can be seen to be built up of several layers of thickening laid down spirally but at varying angles. Again there is the more familiar case of the tertiary spiral thickening of the tracheids of *Taxus*, *Picea*, etc., which, it may be noted (KRIEG[34]), does not follow the striation when this is also visibly present, but is usually at a smaller angle : it is also less developed the thicker the walls, as can be seen in the autumn wood of *Taxus*.

All these cases are end products of the activity of the living protoplasm and the enquiry is pushed back a stage further as to why the protoplasm should lay down the cell wall in this spiral fashion. The obvious suggestion is that the protoplasm with the nucleus directing its activities may itself move in a spiral direction, differentiating and depositing carbohydrate materials as it goes. Unfortunately we have no information as to the movements, if any, of the protoplasm in cambial cells, but for cells of water plants which can be easily studied, JOST[35] (1903) tells us that in elongated units, the rotation of the protoplasm is in a constant direction, following the long axis of the cell and *often shewing obvious torsion* if the cell be exceptionally long, *e.g.*, an R spiral in *Chara*. BRAUN[8] has shewn that the order of development of lateral leaves and roots in *Chara* is related to the direction of streaming, those parts to which the stream is directed developing first : this is important as shewing the connection with the nutritive

function. EWART[36] (1903) finds that in all the cells of the same leaf (in *Elodea* and *Vallisneria*) the protoplasm circulates in the same direction, the spirals of the thickening of adjoining tracheids shewing a similar uniformity. The last mentioned worker also summarises present day opinion concerning protoplasmic circulation to the effect that various stimuli may cause streaming, but not unless the protoplasm has an inherent tendency to streaming, which it often has not. One is tempted to substitute "twist" for "streaming."

The deduction which may be made from the data adduced above, is that the prevalence of spirals within the cell may well be traceable to the spiral course followed by the centre of growth activity* (*cf.* DENHAM[40]).

Considering next the case of a young differentiating tracheid commencing its sliding growth with the wall being built up on a left-hand spiral, and so likely to stretch more easily across the direction of the spiral than along it. The observed facts demonstrate that the slide occurs more readily along a radial plane than a tangential one, *i.e.*, more between cells descended from different cambium cells than between sister cells. Under these conditions, the forces which will result in dimensional growth are likely to be greatest at the top of a square ended cell, and to reveal themselves first at the inner left-hand corner or the outer right hand, as viewed from outside the stem (Fig. 21). These two positions differ in that for the whole inner side there is a tension on both sides of the membrane, since the cell next inwards must be considered as being further on in development whilst the outer side adjoins an actual cambial cell in which differentiation and growth in length has not yet begun : the inner left-hand corner is therefore more likely to bulge first in response to pressure and this it may readily be imagined is sufficient to locate further development preferentially on the left side. All this is of course merely hypothetical.

If this line of argument is correct the tendency must always be present for the fibres to follow a course inclined in the same direction as the spiral of the cell wall, but under ordinary conditions the tendency is presumably insufficiently pronounced to prevail over chance conditions favouring in the average the one course as much as the other : it will require variation in the constitution of the individual plant allowing the tendency to express itself, or a response to some external stimulus. If the cambial cell itself has a parallelogrammic shape viewed along a radius (*i.e.*, in tangential section), the inclination of the top of the cell to the right or left, which would decide the direction of later sliding growth,

* If the spiral course were only once followed in the life of the cell this might suffice to define the lines of subsequent development.

Fig. 21.

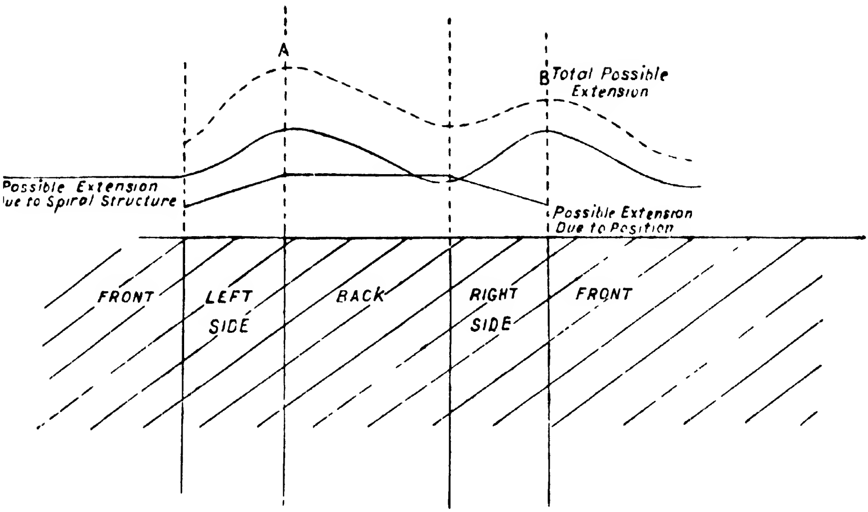


Fig. 21.—Diagram illustrating possible extension during growth of a differentiating tracheid cell of left-handed spiral construction. The cell is represented as opened out on the phloem side, and as viewed from that side.

A = Maximum at the left back (inside) corner.

B = Secondary maximum at the right front (outside) corner.

22. Two-season-old coppice shoots from 6-season-old plants of Malarpali sowings, shewing the effects of local injuries on the course of the fibres. Dead tissues coloured black.

No. **37** "R" unaffected by injury except at its edges. **40** "s" below injury: "2t" above it.

38 "s" unaffected by injury except at its edges **41** "s" below injuries: "s" above them, and,

might be similarly accounted for. The inclined tracheid can then readily be imagined as exerting a back influence on the thin walled plastic cambium cell, overcoming its normal tendency to maintain the vertical orientation and the process could in theory be continued to any degree. With the far more complex structure of angiospermic wood less uniformity is expected and found. It remains to co-ordinate the change of direction of the twist in the course of the life of the tree which takes place in many trees especially conifers. It is well known that in those aquatic plants in which protoplasmic circulation has been most studied, reversion in the direction of flow may be brought about by various stimuli (especially such as are in the nature of a shock) and it may be possible that a change in rate of growth acts in a similar way. Although McCARTHY[14] finds with *Picea rubra* that the change in the direction of the twist is associated with such a change, and for *Pinus longifolia* it has been seen that the change occurs with the onset of old age, the evidence as a whole seems to indicate that the normal condition of twist is left-handed at the commencement of life changing over to right-handed as time lapses at a rate varying with the species. This suggestion should be capable of demonstration, as striation and spiral thickening where these can be detected should shew a parallel reversal. This has been attempted for *P. longifolia*, but on too small a scale to give conclusive results. In R-twisted material 18 cases of R striation were found against 4 cases of L, two of these being somewhat uncertain. With L-twisted wood, 6 cases of L were noted against one of R. It is difficult to find any substantiation for McCARTHY's surmise to the effect that " light is doubtless the factor which determines the direction of torsion," at least without going back to the very origin of life.

(c) EFFECT OF INJURY.

TROUP[16] (p. 44) in summarising recorded information, quotes from SMYTHIES, that "*Damage during youth in unfavourable localities* is the fundamental reason of twisted fibre in the *chir* forests of Kumaon" and that "*fire is a primary cause.*" It remains now to examine this question of the effect of injury on the young plant, bearing in mind that for *Pinus longifolia* only left-handed twist is here concerned. The second assertion quoted is, we consider, amply refuted by the fact that in the whole range of types of locality, straight trees and crops have come up despite annual burning. However the coincidence of the maximum development of twist, both in the individual tree and the crop, with the maximum pressure of the population on the forest and the excessive browsing, trampling and lopping it implies, certainly seems to indicate

that damage to the young plant is an important factor in the matter (*cf.* Fig. 13). In passing, it may be remarked that there is no suggestion of such damage in the quoted example of *Picea rubra.*

Precise data on this point are very few, but some figures obtained from sowings comparing percentages of twist in injured and uninjured seedlings from a single lot of seed are given in Part II, p. 49, where also the apparent lack of influence of the development of the root system is demonstrated. Interesting results, although again only on a small scale, have been obtained from an examination of 2-season-old coppice shoots (from 4-season-old stocks) injured by insect attack in their first season of growth, and presenting a varying degree of callus formation. The course of the fibres in these shoots can be seen in Fig. 22 which shews very clearly that at least in the wood laid down in the year following the injury, the disturbance of the course of the fibres is as a rule very slight, Nos. 39 and 41 being particularly good examples : that exceptions may occur however is clearly demonstrated by 40. In fig. 23 are shewn two examples of the effect of girdling by the same agency, in one of which (No. 32) despite intense contortion in the callus, the fibres a short way above it are as straight as in the original stem, whilst in the other (No. 33) there is but little development in the callus, and the new wood above it is actually straighter than the older wood below. That irregular bending of the stem however caused has little or no effect, is shewn by the figures for seedlings bent or broken by snow given in Part II, p. 49, and by seedling 31 of Fig. 23.

All these data tend to demonstrate that injuries do not generally result in an enhanced development of twisted fibre. They are however open to the objection that a longer period than is covered by the investigations concerned, would probably be required for the effect of the injury fully to shew itself, in fact, one could hardly expect that a change in the orientation of the tracheids or cambium cells far from the seat of the injury, could be effected by the latter, though it is not difficult to imagine such a change spreading gradually outwards from the injury.

Contrasting with these figures are the results obtained by the partial artificial girdling of seedlings by growing them through the holes of a perforated iron plate, reference being made to Part II, p. 50, for details. The conclusion from this experiment is that this partial girdling of the hypocotyledonary zone undoubtedly leads to the development of twisted fibre and often to an intense degree : what is important too, is that the spiral is as often R as L.

In conclusion, it may be remarked that any one conversant with the facts in the field will be biassed in favour of the belief that continued

injury to the young plants at least strongly accentuates any tendency to twist which they may have in them, and this is being made the subject of further research.

The already quoted case of the Almora plantations where under careful protection the young plants, despite very good stem form, shew a high percentage with twisted fibre (*cf.* Fig. 29), also goes to prove that at the best, no injury is requisite for the development of the abnormality. Some experiments on the results of intentional trampling of seedlings have given no very definite results (*cf.* Part II, p. 57).

(*d*) EFFECT OF COPPICING.

A point in the case of *Pinus longifolia* which should repay investigation is the effect of coppicing. In the existing forests which have almost without exception grown up despite annual firing, it is certain that a very large proportion of the trees are of coppice origin. Exception must be taken to CANNING'S statements (*cf.* TROUP,[13] p. 44) that burning back is the cause of, or necessarily results in the development of a bulbous base, and that the fibre of the wood in such bulbous bases is always twisted, since neither statement can be substantiated in the form given, but the displacement of the centre of growth from the original erect stem axis to a dormant lateral bud might easily upset that equilibrium condition in which the tendency of the differentiating tracheids of the main axis to diverge in equal numbers to either side of their neighbours above and below, overrules any unindirectional tendency resulting from growth activities combined with the structure of the growing cell. All injuries moreover act as stimuli tending to reproduce the conditions of a check in the transport of food supplies which has already been seen to be a general accompaniment of specially intense development of twist. The effect of repeated coppicing or other injury would clearly tend to be cumulative.

Such data as are available on the direction of the fibre in coppice shoots as compared with the original axis may be examined. For forest grown plants, the following results have been obtained :—

Series.	Locality.	NUMBER OF		PERCENTAGE BY NUMBER SHEWING TWISTED FIBRE (L)			
		STOCKS.	SHOOTS	Old stock.	Dead leader.	1 yr. old shoots.	2 yr. old shoots.
1	Jaulkande 1	23	46	17	47	0	..
2	Akwabinsar 9	12	24	50	?	?	33
3	Airadeo Firelines (twisted area) .	13	26	92	?	0	31
4	Ditto (straight area) .	20	120	15	?	0	—24
5	Ditto (both areas) .	..	67	?	?	0	31

These figures shew that the new coppice shoots do not develop twisted fibre in their first season of growth, whilst in the second year the shoots still shew twist in a smaller percentage of cases than in the parent stocks. Series 1 is exceptional even allowing that the dead leaders were themselves probably of coppice origin and of uncertain age, whilst series 4 is unique in showing a pronounced tendency to right-handed twist (Fig. 11).

More reliable data have been obtained in experimental sowings made in 1917. A number of plants were coppiced in 1919 and the second strongest shoot examined in 1920 and the strongest shoot in 1921. The results are tabulated below. For comparison the results with normal seedlings of the same sowings are incorporated.

Series.	Origin of seed.	Nature of shoot.	Age of shoot. yrs.	No. of shoots examined.	Percentage by number. Straight throughout.	Slightly twisted.	Markedly twisted.	Remarks.
1	Nainital straight trees.	Original	2	131	89	9	2	
		Coppice	1	70	100	0	0	Note 1.
		Coppice	2	75	84	12	4	
		Seedling	1	..	100	0	0	
		Do.	2	..	83	10	7	
		Do	3	..	94	2	4	
		Do.	4	..	95	3	2	
2	Do . .	Coppice .	1	50	100	0	0	Note 2.
		Coppice .	2	44	75	11	14	
		Original .	2	113	54	20	26	
3	Maharpali twisted trees.	Coppice .	1	48	100	0	0	Note 3.
		Coppice .	2	45	53	27	20	
		Seedling .	1	..	100	0	0	
		Do. .	4	..	51	12	37	

NOTE 1.—Coppiced with clean knife-cut.
NOTE 2.—Coppiced by breaking the stem half through, and bending to the ground (to simulate trampling by cattle).
NOTE 3.—Coppiced with clean knife-cut.

In all cases it is found that as with the 1-season-old seedling, so also for the 1-season-old coppice shoot, no twist is visible even where nearly half the original stems are twisted. The results for the two-season-old shoots are somewhat irregular. In series 1 there is a close agreement with the original 2-season-old stems though the latter shew a slightly lower proportion twisted, and the 2-season-old coppice shoots are definitely more frequently twisted than the 4-year-old seedlings. In series

2, the coppice shoots are definitely more twisted than the 2-or 4-season-old uninjured plants. In series 3, with strongly twisted stocks, there is a close agreement between the 2-season-old coppice shoots, the original 2-season-old shoots and the 4-year-old seedlings. Finally for 46 stocks, the results were recorded individually as follows :—

Condition of original 2-year-old shoot in 1919.	Straight.			Slightly twisted.			Twisted.		
Number of cases.	23			13			10		
Condition of 2-year-old coppice shoot in 1921.	Straight.	Slightly twisted.	Twisted.	Straight.	Slightly twisted	Twisted.	Straight.	Slightly twisted	Twisted.
Number of cases.	13	7	3	10	3	0	2	2	6
Percentage.	57	30	13	77	23	0	20	20	60

Thus out of 23 plants in which the original shoot was straight, the coppice shoot of the same age was still straight in 13 or 57% of the cases. These figures shew that all variations occur though a tendency of the coppice shoot to follow the lead of the original axis is discernable especially if "slightly twisted" is included with "straight," whilst the total amount of twist in the coppice shoots is in very close agreement with that in the original plants.

(*e*) EFFECT OF BURNING.

It may be supposed that the chief effect of burning is similar to that of coppicing by any other means, though the severe shock might produce further results. For instance, an average fire destroys virtually all one-year-old plants and exercises a very severe selective process on the older plants, only the more vigorous surviving apart from fortuitous circumstances. If then the more vigorous seedlings are more liable to develop twist than the weaker, it might still be correct to say that firing increases the proportion of twisted plants. Data are also available from the sowings on this point and full details are given in the second part of this paper but the general conclusions may be repeated :—

"The figures clearly demonstrate that for 2-year and 4-year-old seedlings, there is a pronounced tendency for a higher frequency and degree of twist to be developed in the more vigorous seedlings."

A further range of data offering more conclusive results was collected in 1923 from 1054 2-season-old coppice shoots on 6-season-old stocks of

known origin which were killed back by fire, some being left to coppice naturally, and the burnt stem of others being cut back to within some 3″ of the ground. The details are given in Part II, p. 61, but a very close connection is found to exist between the development of twist in the seedlings and in the coppice shoots derived from them after the loss of the original shoot. This connection is clearly to be traced in all the 18 sets of data collected and is illustrated by the figures of the following table in which only the 5 different seed origins are separated.

Seed Origin No.	% Seedlings free from twist		% Coppice shoots free from twist after 2 seasons.
	After 2 seasons.	After 4 seasons.	
1	83	97	94
2	80	86	85
3	57	71	68
4	55	75	55
5	44	53	48

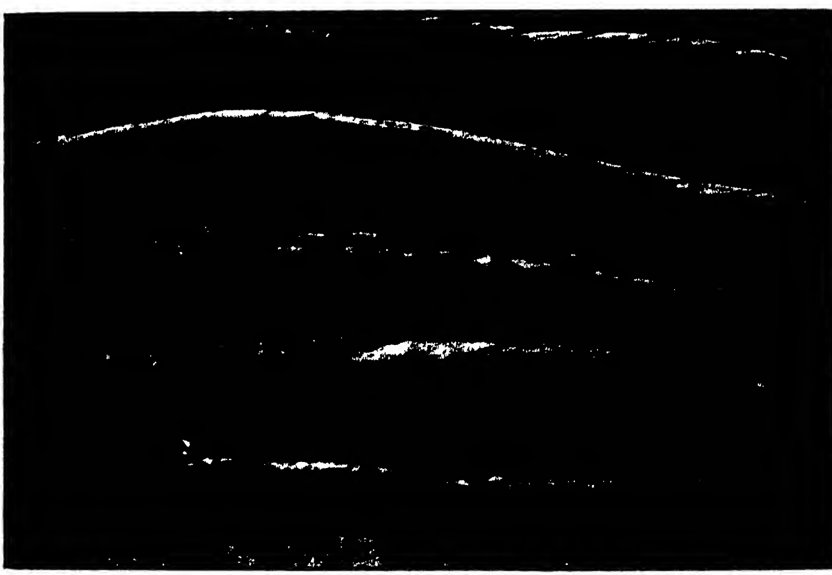
From this also it appears that 2-year-old coppice shoots tend to be very similar as regards the development of twisted fibre to the 4-season-old seedlings of the same origin, and to be rather less twisted than the corresponding seedlings of their own age. Thus simple coppicing does not appear to result in a marked increase in the frequency or degree of twist.

A special form of coppicing very common under natural conditions, especially as a result of fire injury, is what one might call pollarding, when the leading shoot is killed or removed, and growth is continued by a branch taking on the position and function of the leader, or by the rapid development of one or more dormant buds for the same purpose. Figs. 23 and 25 shew some typical results from the sowings, the plants being 6 seasons old, and the shoots 2 seasons. Here again the purely local nature of the effect (or primary effect) of the injury is conspicuous as in No. 43 and No. 45 Of 15 plants carefully prepared for these figures, 9 are straight fibred throughout except in the new callus tissue forming over the old snag, 2 more shew twist in the new shoot than in the dead one, and 2 shew less, whilst in two the base of the old stem has been completely covered. The deduction is that coppicing has not increased the amount of twist in the seedlings two seasons after the operation was made. Similarly of 26 such plants examined in the field, 15 were straight fibred throughout (Fig. 25, No. 46), and 4 twisted throughout (No. 43).

31 32 33 34 35 36

23. 6-season old seedlings from the Maharpali sowings, shewing various injuries and their effect on the course of the fibre

No. 31, Contortion of axis not affecting the fibre (A 2-season-old coppice shoot).
No 32. 33 Insect girdling hardly affecting the fibre. (do.) (do.)
No 34 "Pollarding". "s" below, and "t" above the injury.
No 35 "Pollarding", t „ t „
No 36 "Pollarding", s „ s „



24 Coppice shoots from Maharpali sowings : 2-season-old on 6-season-old stocks : shewing 18°—22° left-handed twist. In Nos. 26 and 27 only a single spiral is inked.

whilst in 4 cases the 2-season-old coppice shoot was more twisted (No. 34) than the 6-season-old stem, the reverse (No. 45) being true for 3 cases : the same deduction is drawn.

The evidence may be summarised to the effect that coppicing does not appear to increase the percentage nor the intensity of the twist in a given seedling or batch of seedlings, but it may introduce a change in the direction of the fibres in the individual. Observations over a longer period are required to show whether the effect may be delayed or gradual and cumulative.

(*f*) OTHER CAUSES.

Finally, it is necessary to mention briefly the rather different case of the young herbaceous or woody shoot, still actively growing in length, which was studied long ago by M. WICHURA[13], DE VRIES[37], and many others since. It can be shewn that the twist found in a horizontal shoot bearing decussate leaves, bringing all the leaves into one plane, is due to the twisting force of the weight of the leaves on the growing cells, and similarly in the case of a petiole shewing twists under the influence of heliotropic or geotropic stimuli, where curvature without twist might be expected to result, the unequal weight of the two lateral halves of the lamina is the activating force.

6. Summary and Conclusions.

SUMMARY.

It is suggested that unidirectional spiral movement of the protoplasm in an elongated growing cell may give a unidirectional spiral structure to the cell wall resulting in a tendency to unidirectional axial inclination in a cell, liable to be emphasised by sliding growth. This latter tendency may be normally corrected by the tendency of the growing cambial cells to repeat the normal vertical orientation and so to resist the back action on them by the sliding tracheids, but very little will be required to allow it to express itself. When it is not so corrected, the degree of twist may increase indefinitely with time. It is further suggested that such a weakening of the controlling forces may occur in all kinds of tree as a chance occurrence after the nature of a "fluctuating variation," but may for certain species in certain localities become an inherited condition. Such an occurrence may be viewed as due to a mutation by "loss" or as the fixation of an acquired character, selection by man having been of considerable importance in the case of *Pinus longifolia* in Kumaon in increasing the proportion of twisted stems : the former view is preferred.

It seems to be the general rule for trees, that in early life the direction of the twist is L in conformance with that of the spirals in the protoxylem

elements, of the striation of the tracheids, and the spirals of their 3ry thickening. But later in life, at a time varying with the species, there is a change over to R; a comparable alteration in the 2ry and 3ry thickening of the tracheid walls has not so far been demonstrated. It is suggested that the protoplasm of the cells during their differentiation may rotate in a similar direction, but this awaits demonstration.

It has been seen that the belief is widespread that unfavourable conditions for the development of the root system is the most general predisposing factor in the occurrence of twisted fibre, and although this cannot be proved for seedlings, it is very possibly correct, due allowance being made for the effects of inheritance. For *P. longifolia*, injury during youth has been believed to be largely responsible for the local prevalence of twist, but examination of seedlings has failed so far to substantiate this belief apart from the fact that it is not supported by the relative absence of twist in many areas equally exposed to seedling injury, and by its frequency in protected plantations. The chief result of burning is to replace seedling growth by coppice ; insufficient data are available, but so far it has not proved possible to demonstrate that the act of coppicing causes any additional twisting. Burning also brings about an elimination of the weaker plants, and seedling examination appear to prove that this action tends to increase the proportion of twist in the surviving seedlings.

Twisting is found to be especially intense at those parts of the axis where abnormal growth activity suggests that for whatever reason, there are local accumulations of food materials ; increased turgidity of the growing cells from this cause may be an important factor in initiating the twist, and if the injury theory proves correct as more precise data become available, it will probably be found to act through this agency.

(b) PRACTICAL APPLICATION.

1. The demonstration that in C. Kumaon, seed from left-handed twisted trees, and from straight trees in a locality where twisted fibre is prevalent, give seedlings a high proportion of which after four seasons of growth exhibit twisted fibre even under optimum conditions of growth, combined with the field observation that twist is not eliminated between the seedling and pole or mature tree stages, emphatically point to the necessity of avoiding the use of seed from such trees in all plantation and artificial regeneration work. The question of the casual twisted tree in an otherwise straight crop is a separate one, and in any case not one of great importance. Right-handed twist in *Pinus longifolia* is, at least as far as ordinary practice is concerned, confined to trees of an age much

greater than will ever be adopted as the rotation age, and so is not to be considered a defect in a tree for seed collection.

2. For the reason that in a locality where twist is prevalent, there are fewer twisted seedlings from seed from straight fibred trees as compared with the proportion obtained from those from twisted trees, in making regeneration markings in such forests, straight grained trees should be selected wherever possible as seed trees.

3. Although the supposition that injury during youth is an important cause of twist, is still *sub judice*, the facts are sufficient to justify all steps to prevent every kind of injury to the young plants especially from fire and trampling.

4. It is possible with experience to recognise twisted fibre in young poles, and in view of the very large proportion of stems normally eliminated in thinnings, it should be possible to remove the majority of the twisted stems as small poles in which the defect is of less importance. The maximum proportion of twisted stems found in 4-year-old seedlings is about 60%. A difficulty is that the twisted stems will be found to include many of the dominant and most promising.

5. Considerable further research is required into the occurrence and causes of twisted fibre. As of special importance may be mentioned :—

(i) The effect on the course of the fibres of restricting the circulation by girdling or banding.

(ii) The effect of damage on straight fibred plants.

(iii) The later development of coppice shoots from straight and twisted stocks.

(iv) The details of changes with age in twisted plants.

(v) The relation between the direction of the striation of the tracheid walls, of the tertiary spiral thickening where present, and of the twist of the fibres.

(vi) The nature and extent of sliding growth in the differentiation of the tracheids.

Of these, the first four are already under investigation for ***Pinus longifolia***.

PART II.—INVESTIGATIONS ON THE POSSIBLE INHERITANCE OF TWISTED FIBRE IN *PINUS LONGIFOLIA* ROXB.

1 Introduction.

In the first part of this paper, the general distribution of twisted fibre in *Pinus longifolia* has been described, and data are quoted there shewing that its prevalence, especially in certain parts of Kumaon, is a serious matter calling for close investigation directed towards finding means of eliminating or reducing the defect in existing and future crops.

A line of enquiry which immediately suggests itself is the possibility that a tendency to produce twisted fibre is an inherent factor in the constitution of a plant shewing it, capable of being transmitted to any offspring produced. SCHOTT[41], SCHOTTE[42], ENGLER[43], CIESLAR[44], KIENITZ[45], and many others have investigated in a variety of species the problem of the inheritance of parental characters under changed environmental conditions, and the results and conclusions reached by them will be touched on below, but none appears to have paid special attention to this particular feature of twisted fibre*. The present writer has been investigating the problem since 1916, in which year preliminary field observations were made and data collected suggesting the lines which should be followed in experimental work. Sowings were made in 1917 in three walled enclosures totalling 2½ acres in Maharpali (Fig. 26) and Khabdoli South (Fig. 27) reserves with seed of five different origins and seedlings have been examined annually up to 1923, *i.e.*, till six growing seasons were completed, and the experiments are still in progress. A fourth enclosure of 1 acre in Sarna Reserve was added in 1919, and a fifth in Kaligadh in 1920. All these enclosures except the last were unfortunately burnt during the incendiary outbreak of 1921, the data collected in that year having been taken mainly from the fire-injured plants. A further inspection of all sowings was made in 1923, when data were collected from the coppice shoots which had come up since the fires, or from plants intentionally cut back. Various control sowings and experiments have also been carried out since 1920 at the Forest Research Institute. Dehra Dun, under the writer's direction.

*SMYTHIES started some sowings of twisted *Pinus longifolia* in Kumaon in 1910 and 1912, but the experiments were only continued into the second season and no record kept of the results which as far as they went, satisfied the investigator that the defect was not transmitted through the seed. TROUP came to a converse conclusion from the results of some very small scale sowings in Dehra Dun in 1912.

43 44 45 46 47

25. 6 season-old coppice stools from Maharpali sowings.

No. **43** "2t" throughout.

44 "s" in stock and dead stump: "t" in coppice shoot.

45 "2t" in stock and dead stump: "s" in 4 coppice shoots.

46 "s" throughout.

47 "s" in stock and dead stump and 2 outer coppice shoots: "t" in central coppice shoot.

aharpali experimental sowings Nainital G sowings 6-seasons old with highly twisted natural pole crop 40 years old in the background.

27. Khabdoh S experimental sowings after 6 seas Overmature 75°/. straight fibred crop in the back

2. Evidence of inheritance in existing crops.

It is possible to make certain deductions from the observed distribution of twisted fibre in standing crops. It is clear (*cf.* p. 8) that right-handed twist is a phenomenon accompanying overmaturity and so is confined to old crops, and it is to be found in most such crops irrespective of special local conditions: the following remarks will accordingly deal with left-handed twist.

The relative prevalence of twisted trees in the pine forests has been worked out a considerable detail for the whole area under *chir* in the Central Almora and Ranikhet Forest divisions. Trees with a twist of less than 7° in the convertible part of the bole* were not considered as twisted, and the percentage of such trees in each compartment or sub-compartment of not over 150 acres estimated by eye. For stock mapping purposes all areas with 30 per cent. or more such "straight" trees were considered as "straight" forests, and those with less than 30 per cent. as "twisted" forests. The map so obtained brings out very clearly what one may easily observe in a general way, *i.e.*, the relative absence of twist in the areas more remote from the centres of population, and its increase up to 100 per cent. of the crop and to an extremely severe degree in the individual, near the older settlements.

In Central Almora division (CHAMPION[31]) in the vicinity of Almora town, 100 per cent. twist is almost the rule, and the average for the range including the town is 79 per cent. Someswar Range, along the Kosi River with a similar pressure of population has 72 per cent. whilst the remaining ranges successively more remote, shew 23 per cent., 20 per cent. and 4 per cent. respectively. Every block of forest brings out the same generalisation, Airadeo, Khabdoli and Bhatkot East being good examples: the outer fringe, especially any exposed tongue-like extension into the cultivation or common grazing land, shews a high percentage and a severe degree of twist, whilst the more central parts are far less affected.

It is thus clear that there is a close parallelism between the occurrence of twisted fibre in a crop and the pressure of population on the forest, and it is this parallelism which has led most observers (CANNING[19], SMYTHIES[20], TROUP[16]) to assume a causative connection, that the prevalence of twist must be due to damage to the trees as seedlings by trampling, browsing, etc. There are however so many factors at work that such causative connection cannot be accepted without proof. It has also to be borne in mind that in these cases of severe twist, one is dealing not with single trees, but with whole

*This limit of 7° was adopted as it was at that time one of the specifications used in passing broad gauge sleepers.

crops, of density at least equal to the average of the "straight" crops, and the suggestion that the high percentage of twist is due to selective fellings among the straighter trees is in itself insufficient to cover the facts. It follows that these twisted crops have come up with their 100 per cent. twisted stems, from the seedling stage, and that either the seedlings were twisted by inheritance from the parent stand or they have become so from the treatment received in youth (since there is nothing to suggest the defect is ordinarily acquired in later life). Many cases can be quoted (Tambadhaun, Pakhura) of a 100 per cent. twisted young crop with remains of an old 100 per cent. twisted parent stand, which are at first sight strongly suggestive of inheritance, but the old crop may have come up twisted under just those conditions of illtreatment predicated as the cause of the twist of the young crop. However, selective fellings of the straighter trees have unquestionably gone on for several tree generations in these areas, and the observed facts would be in full agreement with a theory that a tendency to twist is a character which can be passed on by inheritance, and that the selective treatment to which the forests have been exposed has resulted in an increase in the percentage of twisted stems in proportion to the severity of the selection and the period during which it has been exercised.

Very frequently a fringe of young poles may be found round small clearings or cattle stations well within the "straight" areas relatively remote from the villages (Khabdoli South). Selection fellings have here been neither severe nor prolonged enough to affect the percentage of twisted stems in the old crop, but the percentage in the young poles is always higher than in the old crop though never so high as in a real "twisted" area. The young crop may safely be assumed to have originated from the most vigorous seedlings, and largely from coppice shoots from these, which have survived the annual fires owing to the presence of less grass and litter where grazing and trampling has been heaviest : a severe selection has thus taken place among the seedlings originating from the straight parent trees, and if twisted fibre tends to predominate in the most resistant classes of seedling the result would agree with what is actually found even more closely than if it be assumed that the twist is the direct result of injury to the seedlings by trampling, etc., for in this case, an even higher percentage of twist would be expected than is found, at least in some examples.

THE KAUSANI ESTATE.

An interesting case is that of the Kausani Estate recorded by SMYTHIES and quoted by TROUP[16] p. 44. Here very heavy fellings in mature crops were made some 60 years ago, the only trees left

being for the most part unfit for timber. The groups of poles which have come up over the area are often of good appearance, and are cited by critics of the prevalent forest policy as examples of the possibility of getting good *chir* regeneration with annual burning and moderate grazing. Closer examination of the poles reveals however that a high percentage are twisted, say at least 50-60 per cent., whereas the parent crop would not have had more than 20 per cent. Grazing being relatively light, the cause must be either the firing—but these forests have *all* been fired from time immemorial, and "straight" areas are to be found nevertheless—or inheritance from the selected inferior parent trees.

THE ALMORA PLANTATIONS.

The plantations round Almora also contribute some information. There is no exact record as to the origin of the seed used, but it is very probable that the easily collected cones from low branching trees near the villages, which trees are almost all twisted, provided the greater part. These plantations have been walled and fenced and carefully protected from all forms of injury since their inception, and the boles of the trees are very generally as straight as one would wish despite the extremely low quality of the locality in many parts. At first sight twist is absent and the injury theory substantiated, but examination of the thinnings after barking and a closer inspection of the standing crop (*cf.* Fig. 29) reveals the fact that in Baldhoti as much as 50 per cent. have quite definitely twisted fibre (over 7°).

The following data were collected in September 1923.

Compt. 4, sown in 1892—

(*a*) Of 36 poles, 4″-6″ diameter under bark, 5 were twisted over 10°, and 12 more over 7°.

(*b*) Of 12 fence posts, 4 were over 25°, 3 more over 10°, and 2 over 7°, only 3 being less than 7°.

(*c*) Of 4 dominant trees of 10″ diameter, one was twisted over 25°, and one over 7°.

(*d*) Of 50 trees due for removal in thinnings, 46 per cent. were straight or nearly so, 28 per cent. under 7° twisted, 24 per cent. between 10° and 25°, and 2 per cent. over 25°.

Compt. 3, sown in 1877—

(*a*) Of 100 tall stumps of fire killed trees (*cf.* Fig. 29),
4 per cent. were twisted over 25°
19 per cent. 25° to 10°
29 per cent. 10° to 7°
48 per cent. less than 7°, though many of these were definitely though but slightly twisted.

Parts of Sitoli are better, but it is known that some at least of the seed came from areas (Danpur) fairly free from twist. At the same time two additional points must be noted one being that on the whole the best grown groups on good soil tend to be less twisted than those on poorer soil, in which connection Braun's note may be quoted that " Especially in *Pinus*. I have convinced myself that specimens with shorter internodes usually shew a greater degree of torsion than those with longer ones " The other point contrasting with the first is that the tallest and most vigorous poles include many of the worst twisted. The case of the plantations thus definitely supports the inheritance rather than the injury theory.

TWIST IN NATURAL SEEDLINGS AND THEIR PARENT CROPS.

Over 800 forest seedlings of various ages and from various localities have been examined, as well as an additional 650 from one of the plots used for sowings and 327 standing and 361 felled 30-year poles on another plot. The examination for twist was qualitative rather than quantitative so that strict comparison with the results from the sowings described later is not possible, but the data have an independent value and are tabulated on next page. (For the presen coppice shoots are excluded).

These figures do not reveal a close connection between the percentage of twist in the seedlings and their parent crops, though there is a general relationship: thus the average percentage for seedlings under crops with 50 per cent. or more twist, is 70 per cent., and for those under less twisted overcrops, only 15 per cent. It will be seen later that the lack of uniformity of age is an important matter in this connection. It may also be noted that frequently the percentage of twist in the seedlings is higher than for the overcrop where the latter is relatively free from twist (Nos. 9-11), and conversely (Nos. 15-20, 22). A few vigorous seedlings growing on the loose soil formed by the uprooting of a large tree, shew an unusually high proportion of twist (No 3). Inferior soil conditions (Nos 1, 4, 10, 16, 17 and 23) shew a high proportion of twist in the seedlings, but except in No. 10 the overcrop is also bad.

Examination of seedlings of various ages quickly reveals the fact that twisted fibre is only very rarely indeed apparent in those of only 1 season's growth. In such plants, no single case of strong twist has been found, twist above the cotyledons is very exceptional, and only two or three cases have been noted (among several hundreds in all) of a definite twist in the hypocotyledonary region. Consequently, 1-year-olds recognisable as such have been excluded in the above table. Seedlings of two or more seasons' growth however often shew twisted fibre.

Serial No.	Locality	Sub-soil.	Soil.	Age of seedlings, years.	No. of seedlings.	Percentage of seedlings shewing twisted fibre in any part.	Percentage of seedlings twisted above the cotyledons.	Percentage of twisted trees in over-crop.	REMARKS.
1	Ukhallekh 12 .	Schist . .	Shallow, hard	2—4	74	95	52	100	Heavily trampled.
2	„ 12 . .	„ . .	Average .	2—4	72	86	52	98	Lightly grazed.
3	Khabdoli N. 1 . .	„ . .	Loose and deep.	2	5	80	50	50	On newly overturned soil.
4	„ 1 . .	„ . .	Stiff	3—6	20	95	65	70	Picked good seedlings.
5	„ 2 . .	„ . .	Average .	3—6	19	57	53	50	All seedlings on the area.
6	Khabdoli S. 30 . .	Gneiss .	„	3	20	40	10	30	Random selection.
7	„ 30 . .	„ . .	„ .	3	30	40	3	30	All seedlings on the area.
8	Kulaon 13 . . .	?	„	6—8	8	100	75	95	Very vigorous 4½′ plants.
9	Parkot 10 . . .	Schist . .	„	2—4	20	45	5	25	Random: heavy grass
10	„ 6 . . .	Limestone and schist.	Stiff and hard.	2—3	19	68	0	30	Random selection.
11	„ 6 . . .	Schist . .	Fresh, deep	4—5	12	66	42	25	Deep grass; vigorous seedlings.
12	„ 4 . . .	Limestone	Good . .	2—3	19	58	0	45	Moderate grass.
13	„ 2 . . .	Phyllite .	Average .	1—3	25	20	0	25	Moderate grass.
14	„ 2 . . .	„ . .	Average, deep	4—5	19	53	10	25	Picked good seedlings
15	Akwabinsar 9 . .	Gneiss .	Stiff and hard.	2—1	19	58	0	85	Heavily grazed and burnt.
16	Maharpali 2 . . .	Schist . .	Hard and shallow	2	40	90	53	95	Heavily grazed ridge
17	„ 2 . . .	„ .	Good .	2	40	33	2	95	All together on a cool slope, too steep to be trampled though a good deal grazed.
18	„ 2 . . .	„ .	„	3	20	55	20	95	
19	„ 2 . . .	„ .	„ . .	4—5	20	60	45	95	
20	„ 2 . . .	„ .	„	5—8	12	75	67	95	
21	Jaulkande 1 . .	Gneiss	Average	5—8	12	58	25	30	Repeatedly burnt area
22	Maharpali 5 . .	Schist .	„ .	2—4	152	43	27	100	Heavily grazed, shaded
23	Bhatkot E. 10 . .	Gneiss .	Shallow, dry	2—3	30	70	47	80	Heavily grazed
24	„ 13 . .	Schist . .	Deep moist	2—3	12	80	30	30	Sheltered corner
25	Dhaulchina 20 . .	„ . .	Shallow, hard	2	30	20	3	20	Grazed and trampled ridge.
26	„ 14 . .	„ .	Good deep	2	30	27	10	20	Sheltered slope
27	Bilori 4 . .	„ .	Good average	2—3	165	47	36	95	All in the area; not burnt
28	Maharpali 5 .	„ .	Average	2—6	600	68	52	95	Random selection

"delayed action" in the small seedlings raised in a new locality, they soon disappear as the plants become adapted to their new conditions, but DENGLER[48], working in Eberswalde, Prussia, on about 300 21-year-old trees of each of five origins, found that the difference in height increment admittedly apparent in the early years does not fall off with lapse of time but may even increase. In a very detailed and careful series of experiments he shewed that the plants of northern origin fell behind the local form in sectional increment, in volume, and in leaf production, and as crops, were slower in closing up having smaller crowns with less branchwood: the leafage was also thinner and the needles were shorter, whilst cones were produced at this age on 12-20 per cent. of the trees as compared with only 1 per cent. for the native variety. These differences commonly amount to 50 per cent. of the average quantity in question. HUFFEL's contrary opinion just mentioned is based mainly on some plantations of 1823 from Riga and Alsace seed, pronounced differences having been recorded during their earlier growth but disappearing later, and the Riga plants also not showing the expected fine and straight boles. Sowings at Bellefontaine after 50 years of growth, and others made by VILMORIN [49] in 1831-35 of the alpine form, are stated to point the same way, as also finally do some more recent experiments continued over 10 years. KIENITZ's[45] has made a very detailed study of the regional variation in the grown tree, and observed the growth of seedlings from 12 different localities, at Chorin in Prussia over a period of 15 years: the results fully confirm DENGLER's.

An important article on this subject, in the form of an imposing monograph of 195 pages with 12 plates, 23 figures, list of literature and many tables, was published by Dr. ENGLER[43] of Zürich in 1913, the previous work being discussed and criticised and the author's own experiments described. No later publication of similar type has been traced, so that this has been taken as representing the present position reached by research into the problem, and has been freely drawn on here.

ENGLER's investigations on seedlings were carried out on a scale and with all the care required to give reliable results. Experiments were repeated anything up to 9 times and there were parallel sets of experiments in eleven localities, 2-300 measurements being usually taken to give a good average He found that the differences between the seedlings of different origin, already apparent in the first year, are continued up to at least the 6th year. Differences in the duration of the seasonal growth were especially characteristic, as in his low level area (Adlisberg 670m.), seedlings from low level parents continue growth some 3 weeks longer than those from alpine parents, the cumulative result being naturally conspicuously in favour of the plants of low level origin. The Engadine form he found to differ from the typical alpine form in being more adaptable and doing much better than the latter when transferred to low levels. Engler also records a vast amount of information on cone and seed forms, winter coloration of needles, susceptibility to "Schutte" etc. The work of SOMERVILLE[50]— using

seed received from Engler, in some small scale experiments in England confirmed some of these points.

Picea excelsa.—Precisely similar results have been obtained from spruce, by CIESLAR [44] with 13-14 year-old plants of known origin, and ENGLER[43] with 2, 4 and 5 year-old seedlings. An especially interesting result is one of ENGLER's in the case of certain lowland trees which had been planted high up. The seed of these trees sown in the lowlands gave seedlings which behaved phenologically exactly like those obtained directly from lowland trees.

Larix europœa.--For larch, these two workers have obtained parallel results agreeing well *inter se.* SCOTT-ELLIOT[51] suggests that the better results obtained in Scotland with Tyrolese rather than Scottish seed may be due to incomplete ripening of the seed in Scotland where larch is not indigenous. Again, recorded results for oak, beech, sycamore and *Pinus Laricio* are also similar. ZON[52] records that differences in *Pseudotsuga* from 12 localities in growth habit frost resistance, etc., as tested at Eberswalde persisted in the 2-year old seedlings.

Inheritance of Individual Peculiarities. A different point of view is that of MAYR[28] (of Munich) who holds that the form of *Pinus sylvestris* typical of high latitudes is a species distinct from that prevalent in the south, and that therefore it is to be expected to preserve its characteristics when grown outside its natural range. Sorting out the data bearing on the subject of inheritance of individual peculiarities, the work of ZEDERBAUER[53] at Mariabrunn is of special interest. He sowed seed of individual seed trees separately, noting the breadth of crown, height growth and dominance of each, and after 6 years' growth found that it is necessary to combine the results of several seed trees of similar habit to get any definite results. (Note that nothing is known of the pollen-parent in any case). If this is done, he found with 30 plants that the height growth of seedlings from broad crowned is much more rapid than that of seedlings from dominated trees which are also much more susceptible to *Peridermium* attack than those from dominant trees.*

ENGLER also established some important points: he found at Adlisberg that seedlings from badly shaped marginal trees were indistinguishable from those from well developed trees in the centre of the stand, and conversely that seedlings from selected good trees in a locality of low soil quality (Tiefenkastël and Bonaduz) were much better than those from the badly shaped trees.

*Incidentally, ZEDERBAUER found that the age of the seed tree was of little importance, in which decision Engler is in agreement with him.

TOUMEY[33] found that of 750 seedlings of *Pinus Jeffreyi* from *twisted-fibred parents, some 3½ per cent. shewed a well marked twist below the cotyledons, in the first year* (see below).

ENGLER draws the following conclusions from his own and previous work. "If the bad growth-form of the parent trees is caused by weather effects, or damage by man or animals, the defects are not passed on." "Stem form as such is not heritable in climatic races, but it is the physiological constitution of the tree derived from certain climatic factors which is transmitted." "From these facts it follows of necessity that inferior growth due to the soil can be passed on to the offspring," whether this be considered as inheritance strictly speaking or only "delayed action."*

4. Origin of seed used in the experiments.

Types of seed used.—In the experimental sowings of *Pinus longifolia* seed now to be described, the seed used was mainly from trees of three types which could in actual practice be selected for exclusion from use or used exclusively if the results obtained should indicate such a course as necessary. These are :—

(*i*) Seed from trees growing in a locality where twist is virtually absent—actually from the tertiary sandstones of Nainital division.

(*ii*) Seed from straight trees in a "straight" locality, *i.e.*, in a locality which for Almora district is relatively free from twisted fibre having at least 60 per cent. of the trees straight. Collected in various forest blocks, mainly Khabdoli (parts) and Bhatkot West (parts).

(*iii*) Seed from twisted trees in a "twisted" locality, the converse of (*ii*), from a locality where 80 per cent. or more of the trees are twisted—mostly from Maharpali and Ukhallekh.

In the case of (*ii*) and (*iii*) the exclusion in Indian forest practice of seed from the intermingled twisted and straight trees respectively, essential in experimental work, would admittedly not be practical but would be unimportant.

Further to complete the series, checking results, two other types were used on a smaller scale :—

(*iv*) Seed from twisted trees in a "straight" locality collected from the same crops as (*ii*).

(*v*) Seed from straight trees in a "twisted" locality collected from the same crops as (*iii*).

*KIENITZ, "(1922, p. 87) considers that it follows from the results with the data for whole sowings, that individual peculiarities must be inherited and that it is waste of time to attempt to demonstrate it, he also quotes (*loc. cit.* p. 88) examples in the forest he considers equally conclusive.

It must be remembered that this classification is based entirely on the carpellary parentage of the seed and overlooks entirely and inevitably the pollen parentage. For (*i*) the strain may be pure, generally speaking, whilst for (*ii*) and (*iii*) the probabilities are 60 per cent. and 80 per cent. in favour of, and for (*iv*) and (*v*) 60 per cent. and 80 per cent. against similarity in the two parents.

The Nainital seed has been supplied by the divisional forest officer on two occasions from Mongoli and Okhaldhunga. Very good germination was obtained and the seedlings have done well.

Practically all the rest of the seed for the original sowings was collected by the writer personally. It was extracted from the cones by sun heat only. For the later sowings assistance was also obtained from attached and range officers, similar care being taken. Judging from the germination obtained, all seed used was of good quality. Although the bulk of the seed for (*ii*)—(*v*) was obtained from the two localities, Khabdoli South, and Maharpali, where the experiments were carried out, seed from other areas was also used in conformity with the plan of making only such distinctions as could be continued in practice.

5. The experimental areas.

Experimental sowings have been made in five localities.

Date.	Serial No.	Locality.	Underlying rock.	Aspect.	Alti-tude.	Area in acres.	Surround-ing crop.
							Per cent twisted.
1917 . .	1	Maharpali .	Mica Schist .	N.W.	[illegible]	1	100
1917 . .	2	,, .	,, .	N.W.	5,000′	½	100
1917 . .	3	Khabdoli S. .	,, .	S. .	5,500′	1	6
1919 . .	4	Sarna . .	Limestone .	E.	4,000′	1	60
1920 . .	5	Kaligadh 2 .	Mica Schist .	S.E.	5,500′	½	5
1920 . .	6	Dehra Dun .	Alluvium .	Flat.	2,500′	..	..

Nos. 1 and 2 were intended to check against each other, the sowings being under identical conditions, thus Nainital seed was sown in plot N of No. 1, and G of No. 2. No. 2 (Fig. 26) is the half acre from which a dense young pole crop was cleared and examined. The locality was selected as one where conditions appear very favourable to tree growth, but which carries an intensely twisted old overcrop giving equally twisted regeneration—it is thus a "twisted" locality. No. 3 Khabdoli S. (Fig. 27) was chosen to resemble No. 1 as closely as possible in all physical factors, but situated in a "straight" locality. No. 4 was added later to include a different type of soil and subsoil; conditions are favour-

able to tree growth as seen in fine height growth of the old trees, but the crop only just gets into the "straight" class. The Ranikhet area (Kaligadh 2) was added in 1920 primarily for carrying out some special experiments at a convenient centre. Control sowings have also been made by the Sylviculturist at Dehra Dun but owing to conditions being unfavourable to *chir* seedlings, very few have survived. Nos. 1 and 3 are the most important with complete sowings in 1917 whilst the Maharpali plots, where a larger number of seedlings has been available, have provided material for the many subsidiary experiments.

Sowings in the Maharpali plots were made by the writer personally, whilst in Khabdoli and Sarna, this was done by Pt. Bhawani Datt Pant from whom considerable valuable aid was received. The sowings were made at the commencement of the rains in prepared strips 5′ long running along the contours No weeding or transplanting has been done, but the grass has been cut annually. The plantations were walled to exclude grazing animals with the exception of Sarna, which could only be wire fenced and so not very effectively protected. From the commencement of the sowings, every seedling suspected of chance introduction from the surrounding forest has been at once uprooted -only in the first year was there any danger of error from this source and even then it was inconsiderable. Periodic inspections have been made, in which help has been given by Mr. W. F. Coombs (as also in seed-collection), apart from making measurements the whole of which has been done by the writer.

It may be noted here that owing to the much larger quantity available, the Naini tal seed was sown much more densely than the other lots. In this case only was there any marked degree of competition between the seedlings for light and space.

In selecting seedlings for removal and examination, special care was taken to avoid any kind of selection of the more vigorous or of the inferior plants, except where the converse is expressly stated.

6. The examination of the seedlings and the record of results.

THE SEEDLING.

Troup in his monograph on this species, gives excellent descriptions and illustrations of the seedling at different stages of its developement and only a few additional remarks are required (*cf.* Fig. 20). The 1-season-old seedling when quite fresh is readily stripped of its bark for examination, the course of the fibre being easily seen, as lines of paler coloured elements emphasise it. At the insertion of the cotyledons there is a slight swelling of the woody axis, the vascular bundle of each cotyledon being often distinguishable. About 1/10″ to 1/20″ above this swelling a whorl of buds is usually conspicuous, buds which often remain dormant but which are of great value to the plant in case of injury to the leader: they are also commonly

developed without such injury when the soil is shallow or conditions are otherwise bad. The hypocotyledonary region is clearly defined being above ground and devoid of side roots or leaves: at this stage it is usually found to be flaking off a few thin and long strips of bark. If the seedlings are allowed to get dry, it becomes very difficult to peel off the bark clean as required for ready examination.

In the second and following seasons, the same features can be traced, but the swelling marking where the cotyledons were inserted becomes less and less definite till it is finally lost. The cortex of the hypocotyl and the adjoining lower part of the stem [for about an equal length in the 2-3 season old plant, *cf.* Fig. 20(2)] often grows very rapidly forming a carrot like expansion of soft juicy tissue, green in colour and soon beginning to flake off barky scales. When the plant has reached a height of 1½′ or more, a sharply defined carrot is usually lost, as it becomes tapered off upwards. The woody axis is very uniformly cylindrical and shews no trace of additional growth beneath the carroty cortex when this is present. The carrot also has its biological significance in protecting the life of the seedling especially against fire, forming an insulating covering over the dormant buds in the axils of the juvenile leaves. The bark is easily peeled off clean with the finger nail after a strip has been removed along one side with a knife.

METHOD OF EXAMINATION.

The seedlings to be examined were carefully uprooted by hand with the root system as complete as possible, shaken free of earth and measured up partly before and partly after removal of the cortical tissues

For every seedling of the main series the following data were recorded :—

1. Height above ground in inches.
2. Vigour in 5 classes, (very vigorous: vigorous: normal: weak: very weak).
3. Length of root in inches (excluding part under 1/20″ diam.)
4. Condition of root system in 5 classes (straight, nearly straight, crooked, digitate or forked).
5. Condition of lateral shoots in 4 classes (nil, small, bushy, dead).
6. Branching in 3 classes (normal unbranched: two leaders: with whorled branches).
7. Development of foliage in 4 classes. (Juvenile, Juvenile+few adult, Juvenile+many adult, adult)
8. Degree of carrot formation in 5 classes. (Very strong, strong, moderate, slight, nil).
9. Diameter over all at insertion of cotyledons.

10. Diameter of woody axis at insertion of cotyledons.
11. Degree of twist in four sections of the woody axis.
    (*a*) Upper stem—for 10 diameters above (*b*).
    (*b*) Base of stem—for 3 diameters above insertion of the cotyledons.
    (*c*) Hypocotyl—the one inch length below the insertion of the cotyledons.
    (*d*) Root—the portion 1″—3″ below the insertion of the cotyldons.

In 1917, the degree of twist was estimated by eye only in 4 classes—nil (=straight), slight (½), twisted (t), strongly twisted (2t). It was then considered better to standardise these measurements and a sample lot sorted by eye were found to have the following angular inclination of the tracheids :—

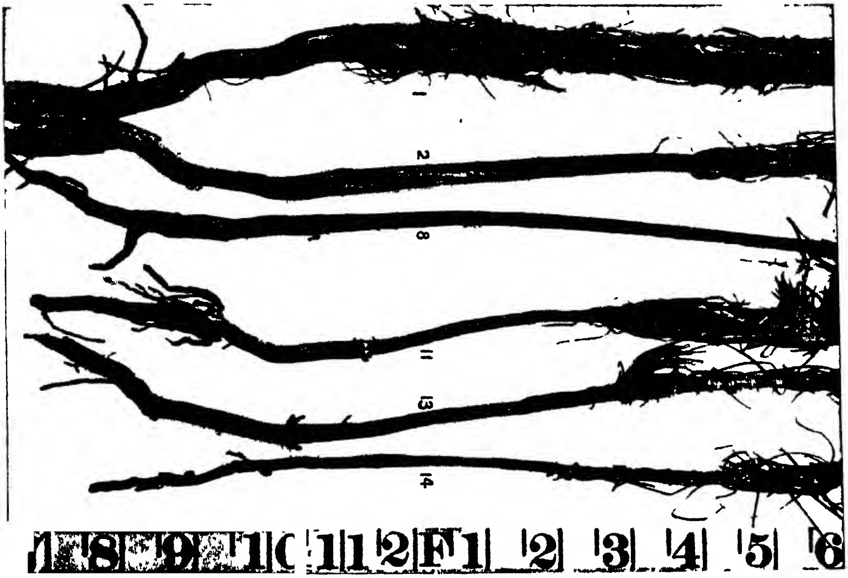
s=0 –5°
½=5° –15°/10°
t=15° –25°/20°
2t=over 25°

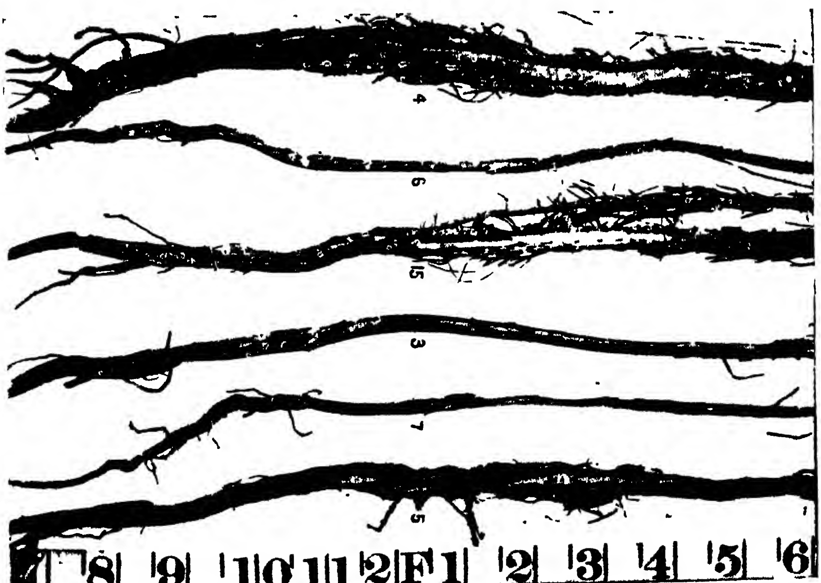
A seedling recorded as s ½ t ½ is accordingly one with upper stem straight, lower stem slightly twisted, hypocotyl twisted and root slightly twisted.

In subsequent years, each seedling was checked against a specially made scale with these divisions. Reference to Fig. 28 will elucidate this matter.

With four twist classes in four sections of the axis, 64 combinations are possible apart from the theoretical possibility of additional combinations up to a total of 2401 with the corresponding three degrees of negative or right-handed twist. To simplify this, right handed twist is better overlooked and this has been done in preference to the possible alternatives of cancelling it against an equivalent of left handed twist, or of entirely excluding affected seedlings : it has already been noted that the 2-season-old plants showed no right handed twist. This matter is further discussed on p. 57. The possible 64 combinations, a considerable proportion of which have been actually found (a selection being shown in Fig. 28), have further been grouped together into 6 classes as follows :—

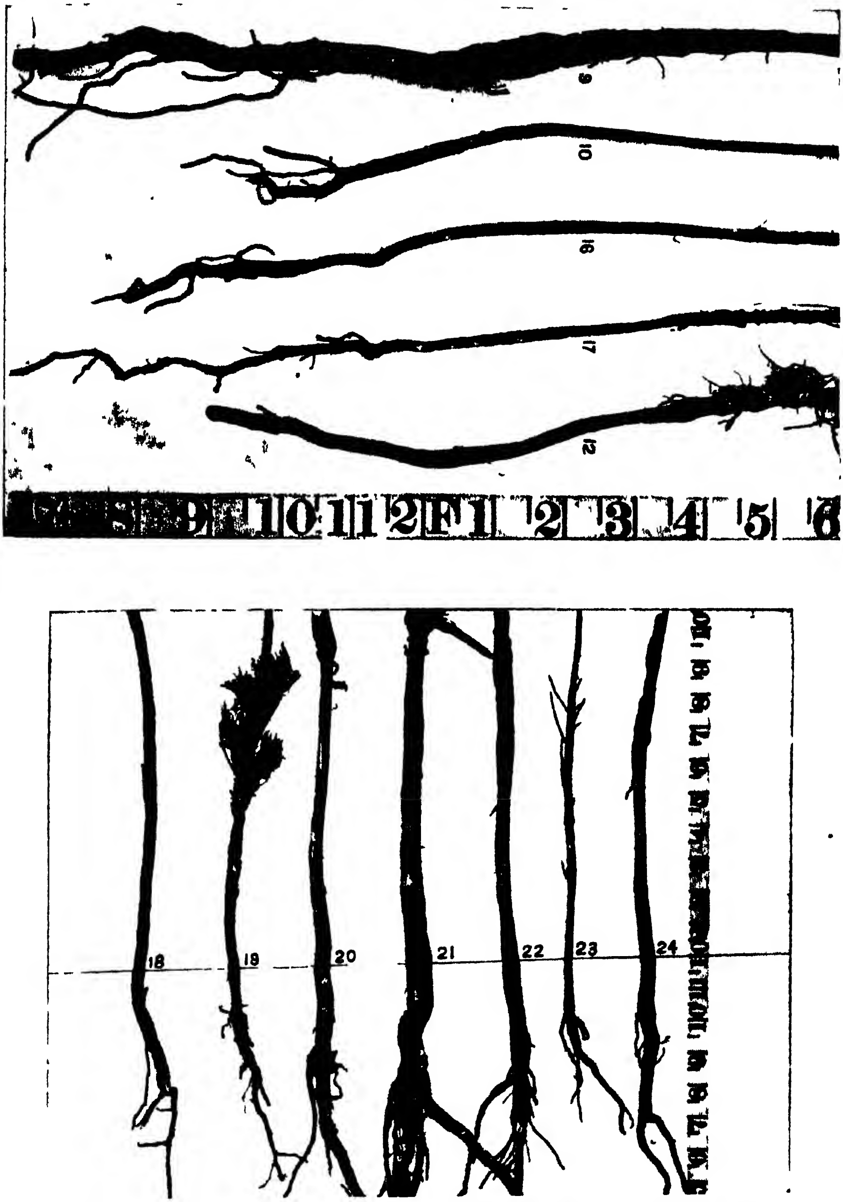
A1 or 4 S (0)	ssss only. (No. 15).
A2 or 3s. (1)	ss½s, ss½½, s½ss, ½sss. (cf. No. 11).
B. or 2s (2)	all ssxx (No. 8) except those included in A, and including s½½s, ½s½½ and ½½ss. (No. 20).
C or s½ (4)	all s½xx and ½½xx except those included B or E.
D or st (6)	all st xx (Nos. 10, 16), ½t xx (Nos. 7, 9) and ttxx, (Nos. 5, 19, 21) except those included in E.





28. A-B. Sample two-season-old seedlings from the Maharpali experimental sowings, shewing variations in the course of the fibres and allotment to the several twist "classes". For explanation *see* text, p. 46.

1	s. s. 2t t	11	s. s. R/2. s	4	t 2t. 2t. t	3	½. t. 2t. t
2	s. s. 2t. ½	13	R/2. R. ½ ½	6	½. t 2t. t	7	½. t.t. t
8	s. s. t. ½	14	s. t. R/2.½	15	s. s. s. s	5	t. t t. ½



28, C-D. Sample two-season-old seedlings from the Maharpali experimental sowings, shewing variations in the course of the fibres and allotment to the several twist "classes". For explanation *see* text, p. 46.

9	½. t. s. s.	**17**	s.t. ½. s	**19**	t. t. t. ½	**22**	R/2. R. R. s
10	s. t. s. s	**12**	s. s. 2t. t	**20**	½. ½. s.s	**23**	R. R. R. s
16	s. t. t. s	**18**	t. 2t. t. ½	**21**	t. t. t. ½	**24**	s. R/2. R s

E or s2t (8) . . . . . all with 2t in any part. (Nos. 3, 4, 6, 18)

FACTORIAL REPRESENTATION OF TWIST.

It has also been considered helpful to express numerically the average twist in a given lot of seedlings. To do this, arbitrary values have been assigned to each of the six classes as shewn in brackets in the table above. It makes no difference to the comparative results if the strict sequence of numbers 0, 1, 2, 3, 4, 5 is taken, but the enhanced figures for the later classes is considered to express more clearly the greater significance of the extension of the twist to the stem itself, and the wider angular range of each successively higher grade of twist. For coppice shoots, a modification is adopted in that cuttings from A1, A2, and B are all 2s, and must be valued at 0, so E is increased to 12, C is subdivided to s. ½=2, and ½. ½=4, whilst D is divided into D1 or s. t = 4, D2, or ½. t.=6, and D3 or *t. t.* =8.

The following figures are from Maharpali and Khabdoli only except where the contrary is expressly stated, as only one set of measurements has been made in Sarna (in 1923), and none in Ranikhet.

It has been accepted as a standard that for a trustworthy average, at least 100 seedlings should be examined, and wherever possible a large number. In a few cases 100 seedlings were not available, whilst in others many times this number were examined, *e. g.*, in 1917, in Maharpali 400 Nainital seedlings from Plot N. and 550 from Plot G.

7. Statistical Investigation.

In 1919, with the 2-season-old plants, the data were analysed in considerable detail with the object of detecting possible errors which might destroy the value of deductions made from the measurements or obscure the results. Further similar analyses were made in 1920 and 1921 chiefly for purposes of check. Thus it was thought possible that (i) the *average vigour*, (ii) *root development*, (iii) *injury to the stem* and (iv) *degree of carrot formation*, might all have this effect. It has been seen above with forest seedlings, that (v) the *age of the seedling* is of importance, and it was also important to find out (vi) what *range of variation* was to be expected with experiments repeated under similar conditions, as for the Nainital seed in plots N. and G. of Maharpali.

(i) *Influence of general vigour.*

Every set of data which has been thus analysed indicates that the degree of vigour has a definite relation to the degree of twist, *i.e.*, the more vigorous the seedling, the more likelihood there is of its being twisted. The following sample sets of figures will demonstrate this point : for the 1919 series, the 5 vigour classes have been condensed to three, whilst in the 1921 series the two subnormal classes are omitted.

Series.	Origin of seed.	Age of seedlings.	Vigour Class.	Number of seedlings.	TWIST CLASS AND FACTOR A1=0	A2=1	B=2	C=4	D=6	E=8	Total twist.	Average twist.	Twist class of average.
		Years.			Total twist in class by factors.								
1	Khabdoli: straight trees in "straight" locality	2	Weak	106	0	24	16	12	12	0	64	0·63	A2—
			Normal	263	0	42	98	60	120	16	336	1·28	A2+
			Vigorous	257	0	29	96	136	222	144	627	2·44	B
2	Nainital: straight trees in "straight" locality.	2	Weak	149	0	16	8	8	0	0	32	0·22	A1
			Normal	171	0	29	42	44	12	0	127	0·74	A2—
			Vigorous	80	0	18	30	56	78	16	198	2·48	B
3	Nainital: straight trees in "straight" locality.	4	Normal	186	0	11	14	16	18	0	59	0·32	A1
			Vigorous	66	0	2	0	4	6	0	12	0·18	A1—
			Very vigorous	27	0	1	0	0	0	0	1	0·04	A1—
4	Maharpali: twisted trees in "twisted" locality.	4	Normal	115	0	8	6	44	240	16	314	2·78	B+
			Vigorous	26	0	3	0	28	48	0	79	3·03	C—
			Very vigorous	10	0	0	0	8	24	8	40	4·00	C

It is seen that there is generally a difference of a whole twist grade between weak and normal seedlings and again between the normal and the vigorous ones, although as might perhaps be expected, this may not be apparent in a lot almost free from twist (series 3). This introduces a complication which can only be completely circumvented by using only equal proportions of the several vigour classes when comparing two lots of seedlings, or by making comparisons only between the same vigour classes. As the closest practical approximation to one of these courses, all seedlings of subnormal vigour have been omitted and only the normal and vigorous plants used, *i.e.*, those which in the forest might be expected to survive to reach the tree stage.

(ii) *Influence of Root Development.*

The 950 Nainital seedlings examined after 2 growing seasons at Maharpali, on analysis for the effect of root development on the occurrence of twisted fibre, give the following result :-

Root group.	Number of seedlings	Straight throughout	Twisted below cotyledons only	Slight twist above cotyledons.	Pronounced twist above cotyledons.	Average twist on factors
		A1 +A2	B	C.	D+E	
		PERCENTAGES.				
Normal	690	69	15	8	8	1·1
Slightly crooked	89	73	13	6	8	1·0
Crooked	126	75	12	8	5	0·9
Digitate	45	67	15	9	9	1·2
ALL	950	70	15	8	7	

The variations between the different classes are absolutely negligible, the average twist on the factorial method falling in each case very close to the value of 1·0 taken for the A2 group. The deduction seems accordingly quite safe that for these young plants, root development is unimportant in this connection.

(iii) *Influence of Injury to the Stem.*

No connection has been traced between accidental injuries to the stem and the development of twist, though the data are at present insufficient to establish the point firmly. Out of 42 2-season-old plants recorded as having received injuries of various forms to the stem, 65 per cent. fall into the A1 and A2 classes, 12 per cent. into B, and 23 per cent. into the more twisted classes, as compared with 71 per cent., 17 per cent. and 12 per cent. for the whole number of seedlings including these injured ones. Again out of 39 seedlings broken by snow at the end of their first-growth season, 72 per cent. were found after the second season

to fall into the A1 and A2 classes as compared with the normal 71 per cent. Further data on this important point are being collected, some being described in the following paragraphs, but in discussing the results obtained from these sowings, it seems fair to assume that injuries to the stem may be left out of account : actually injured stems are here so few as to be of no importance in any case.

A special set of experiments to investigate the effect of partial girdling of various types on the direction of the fibres was initiated at Ranikhet and Dehra Dun in 1921.

A series of young poles were tightly bound with wire at a height of 1′ 9″ from the ground, and a second series had a 6″ strip of bark removed from each side of the stem at a similar height, in such a way as to leave one quarter of the total circumference intact in two strips symmetrically placed, one on each side of the stem. Data have not yet been collected from these trees.

Secondly, seedlings were grown through holes in a perforated iron sheet for examination after they had developed to a size at which the holes were too small to allow of normal girth growth ; the Ranikhet experiment was a failure, but as a result of special care, plenty of seedlings were obtained at Dehra Dun, and examined at the end of the third season in 1923, examples being illustrated in Fig. 30. 113 seedlings were so examined, of which 56 (Set A) shewed pronounced expansion of the woody tissues (as well as the cortical) above the hole ; 28 (Set B) had a definite constriction of the wood at the hole, but no specially marked swelling above it, whilst the remaining 28 (Set C) shewed little or no swelling or constriction, though not a few had minor injuries at the point of contact. The seedlings being close together and kept in a rather shady spot, were all rather drawn up, unbranched, and with few or no adult needles, but the majority were quite vigorous in appearance. Root development was generally poor, and the experiment could not be carried on largely on this account.

The results, illustrated by Fig. 30, were somewhat unexpected and are summarised as follows :

Definite R twist	in swelling, with	t	above it in	1 plant of Set A,	0 of Set B, &	0 of Set C
R	,,	s	,,	15 ,,	,, 2 ,,	0 ,,
R	,,	R	,,	4 ,,	,, 0 ,,	0 .
L	,,	t	,,	4 ,,	,, 6 ,,	4 ,,
L	,,	½	,,	5 ,,	,, 4 ,,	2 ,,
L	,,	s	,,	12 ,,	,, 1 ,,	1 ,,
No Twist	,,	R/2	,,	0 ,,	,, 1 ,,	0 ,,
Do.	,,	s	,,	0 ,,	,, 8 ,,	20 ,,
Do	,,	½	,,	0 ,,	,, 0 ,,	2 ,,
Do.	,,	t	,,	0 ,,	,, 1 ,,	0 ,,
Definite R & L twist symmetrical to a vertical axis through the point of least swelling			in	12 ,,	,, 5 ,,	0 ,,
Asymmetric R & L folding in swelling			,,	3 ,,	,, 0 ,,	0 ,,

29. A stump of a 45-year-old tree in Baldhoti Plantation, C. 8, shewing intense left-handed twist decreasing upwards. Note the well-shaped poles of the crop in the background.

A13 A15 A50 A29 B30 B74 C10

30. Partially girdled 3-season-old seedlings grown at Dehra Dun through a perforated iron plate.

A13 Intense R in swelling, "s" above cotyledons.
A15 Strong asymmetric R and "t" folding in swelling : "ʇ" above cotyledons.
A50 Strong "t" in swelling : "t" above the cotyledons.
A29 "s" throughout except for symmetrical deflection round the sides of the cambial injury.
B30 R and L twist symmetrical to the vertical axis through the points of least swelling
B74 Straight fibred throughout.
C10 Straight throughout.

The girdling thus undoubtedly causes twist and often to an intense degree. For Set C, where girdling has hardly commenced, only 21 per cent. of the plants shew appreciable twist (all L), whilst for Set B the figure becomes 46 per cent., and in Set A, only 21 per cent. are free from twist the twist being now equally R and L, and far greater in intensity. The striking feature is this development of a high frequency and intensity of R twist. The proportions of R and L are what would be expected with an equal tendency to develop twist in either direction, and are paralleled in no other set of experiments here described. It is however to be kept in mind that the swelling and accompanying twist in the fibres is here confined to the hypocotyledonary region which has already been seen to be, and would theoretically be expected to be the region most inclined to abnormality and irregularity in this respect. In no case could the induced twist be said to have extended above the insertion of the cotyledons, though nearly two complete revolutions as a maximum occurred below them in some cases. The experiment requires repetition and continuation for a longer period to be conclusive. A further observation concerning the effect of injury to the stem was made on these plants. Contact with the edges of the hole had in not a few cases killed the cambium over an area of varying size. Where callus formation has set in, it was found that as a rule the new fibres were merely displaced roughly equally to the right and left round the edges of the wound, presenting an appearance as though with the closure of the latter no displacement would remain visible. Where however the wound was extensive enough to cause a swelling of the tissues above by partial girdling, the effect on the direction of the fibres was similar to that caused by the other form of girdling.

(iv) *Influence of Degree of Carrot Formation.*

The appearances connected with the development in the seedling of a carroty base are decidedly confusing. Its maximum development, *i. e.*, with the greatest ratio of diameter to length of the swelling, is found in seedlings of rather poor appearance whose growth vigour seems to have been diverted from the main stem to lateral branches originating from the dormant buds close above the cotyledons. It is however also commonly a feature of the most vigorous seedlings of a healthy sowing, being less developed in those individuals which stand too close together or are being overtopped by stronger neighbours. It is suggested that the immediate causes of these two maxima must be different, but that there must be a common ultimate cause. In Part I, page 18, it is further suggested that local accumulation of food materials may be this ultimate cause.

Examining the results of classifying the twist grades for each of the five carrot classes separately in a given lot of seedlings, it is found that stronger carrot development is unquestionably accompanied by a higher average twist. The best example is taken from the 262 two-year-olds examined from seedlings of all origins in Khabdoli. The percentages of A1 and A2 seedlings for the successive carrot grades beginning with the strongest are 13, 27, 37, 49 and 64--approximating closely successive multiples of 12. The actual figures for the four largest sets of seedlings are :

Series.	Origin of Seed	Number of seedlings.	AVERAGE TWIST FOR EACH CARROT GRADE.				
			nil	slight.	moderate	strong	very strong.
1	Nainital G.	550	0·2	0·4	0·8	2·8	2·4
2	Nainital N	400	0·1	0 8	1·4	1·8	1·9
3	Straight Locality ; Straight Trees.	626	0·5	1·9	1·8	2 0	2·1
4	Twisted Locality ; Twisted Trees	365	1·2	2·4	3 9	4·3	4·8
	AVERAGE		0·5	1·4	2·0	2 7	2·8

As the classification into carrot grades is purely ocular, the regularity of these figures is as marked as could be expected and there can be no doubt as to the general tendency. This conclusion is perhaps even better brought out in another way by condensing the carrot groups into two, the two lesser and the three greater. This is done in the following table :-

Series.	Origin of seed.	Number of seedlings.	Carrot formation.	PERCENTAGES IN EACH TWIST GRADE.					
				Twist grades.					
				$A_1+A_2(=0)$ (not separated).	B(=2)	C(=4)	D(=6)	E(=8)	Average twist.
1	Nainital .	215	Weak.	89	9	1	1	0	0·3=A1
		335	Strong.	64	18	7	9	2	1·3=A2
2	Nainital .	268	Weak.	90	6	3	1	0	0·3=A1
		132	Strong	56	19	14	10	1	1·6=B
3	"Straight" locality (Khabdoli); straight trees.	238	Weak.	80	12	2	6	0	·7=A2
		388	Strong.	51	20	12	12	5	2·0=B
4	"Twisted" locality (Maharpali); twisted trees.	127	Weak.	53	22	6	18	1	2·0=B
		238	Strong.	19	14	11	45	11	4·3=C

It is seen that in only one out of the 20 double entries, do seedlings with strong carrot shew less twist than those with weak carrot development, and that the difference is very pronounced in all the remaining 19. In each set the average twist for the seedlings with well developed carrot is a grade higher than for those without it. From these figures it is clear that any connection which might be traced between the development of twisted fibre and the origin of the seed must be re-examined with regard to the possibility that a lot of seedlings with higher twist development may not be simply a lot with a high proportion of carroty plants. If twisted fibre *causes* carrot development a hypothesis which could justifiedly be based on the data just presented the connection traced would naturally still stand, but this hypothesis would first require proof and so it is preferable to work up the data after eliminating as far as may be, this possible source of error. Exclusion of one only of the carrot grades cannot be justified, so it would appear best to use at least approximately the same proportions of the several grades in each set of seedlings. Actually it is found that in the five sets already referred to in this section, the percentages of the totals examined, for which a greater degree of carrot is recorded are :- Nainital N. 33 per cent. : Nainital G. 61 per cent. : Straight locality, straight trees, 62 per cent.: Twisted locality, twisted trees, 65 per cent.; and Khabdoli (all) 60 per cent. After the elimination of the seedlings of subnormal vigour, these figures become 51 per cent., 66 per cent., 73 per cent , 74 per cent. and 63 per cent. respectively, and are sufficiently similar to exclude the introduction of any serious error on this account.

A very interesting set of figures was obtained for 100 natural seedlings growing at Mongoli, in Nainital division, under the trees which supplied most of the Nainital seed used in the experiments. The percentage of A, B, C and D twisted seedlings was found to be 90, 7, 2, 1. From the Maharpali sowings, Nainital N plot, 79, 10, 7, 4 would be expected, but if a calculation is made dealing with each carrot class separately and totalling them in the same proportions as they were found in the natural seedlings, the percentages become 87, 7, 4, 2 in striking agreement with the figures actually found.

(v) *The Age of the Seedlings.*

Investigations on forest seedlings brought out clearly for them that the amount of twist increases with the age of the plant, being nil in the first growth season, appearing abruptly in the second, and thereafter becoming gradually greater. The following table compiled from the sowings in Maharpali, shews the results there obtained with 2-3-4 and 6-season old plants (weak plants being excluded).

Series.	Origin of seed.	Age yrs.	Number of Seedlings.	Percentage A1 plants.	Percentage of C, D & E plants.	Average Twist.
1	Nainital G.	2	499	60	13	1·1 = A2
		4	150	91	2	0·2 = A1
2	Nainital N.	2	251	50	17	1·3 = A2
		3	278	82	5	0·5 = A1+
		4	122	89	5	0·3 = A1
3	Straight Locality . . .	2	520	41	24	1·9 = B
	Straight Seed	4	122	77	15	1·0 = A2
		6	28	86	11	0·7 = A2—
4	Straight Locality . . .	2	96	38	38	2·8 = B+
	Twisted Seed	4	97	47	47	2·5 = B+
5	Twisted Locality . . .	2	113	29	50	2·3 = C—
	Straight Seed	4	96	54	24	1·8 = B
6	Twisted Locality . . .	2	315	16	58	3·9 = C
	Twisted Seed	4	151	40	50	2·9 = B
		6	24	16	58	4·1 = C

It is at once seen that these figures do not bear out those collected from the forest seedlings. During their development from the 2nd to 4th seasons the percentage of A1 seedlings has everywhere increased very considerably—usually to more than 1½ times the original figure—and the average degree of twist has improved into the next better class in each case. The 6-year-old plants are too few in number to give any conclusive results, but such as they are, they shew a still further increase of A1 for seed of straight origin, but a return to the 2-year figures for those of twisted origin. For the present these data can only be taken as a further indication that to be comparable *inter se*, seedlings must be examined at the same age. It may be noted as a possible hint at the reason, that these sowings have been carefully protected from all forms of injury (excluding the 6-year-old plants) and as mentioned on page 38, the one set of forest seedlings giving a somewhat comparable result is also the only one which had not come up under heavy grazing.

Before leaving this topic, two possible explanations and objections must be mentioned. Firstly in the case of the forest seedlings, the age of the more vigorous seedlings (which, as we have seen, will be the most

twisted at any fixed age) will probably have been overestimated—this is undoubtedly the case, but hardly in sufficient degree to account for the data quoted; further, one might suppose that the real connection is between twist and the development stage reached by the seedling at the time of examination and not its actual age, but as it is very difficult to devise a really suitable scale of such stages, this supposition must be left over for the present. The second matter is referred to in Part I, p. 27, and is that the natural seedlings are only the survivors of a severe selective elimination which has hardly touched the artificial sowings.

(vi) *Range of Variation.*

The two sowings of Nainital seed in plots N and G of Maharpali were made in order to give indications of the range of variation to be expected, and the results after 2 and 4 seasons are given as well as the figures for 2-season-old coppice shoots from the 4-season-old stocks.

The following table brings together the results after elimination of weak seedlings and shoots.

Plot.	Age years.	Number of Seedlings or shoots	Percentage in each twist class: A1	A2	B	C	D	E	Average Twist.	
N .	2	251	50	19	14	10	6	1	1·3	A2
G .	2	499	60	12	15	6	6	1	1·1	A2
N .	4	122	89	3	3	3	2	0	0·3	A1
G .	4	159	91	6	1	1	1	0	0·2	A1
N .	2 (coppice)	109		93		5	2	0	0·26	A1
G .	2 (coppice)	97		90		10	0	0	0·23	A1

The agreement throughout is better than would be expected, especially as regards the average twist, and indicates that the method adopted is sufficiently accurate for the object in view. It has already been mentioned, and is repeatedly brought out in the calculations made, that small numbers of seedlings cannot and do not give reliable percentages.

(vii) *Miscellaneous.*

Under forest conditions, there are still further factors influencing the growth of the seedlings, whose effect may be of importance especially in the struggle with competing grass and other vegetation. *Height*

growth is such a factor, and the Khabdoli data for 262 two-season-old seedlings of all origins have been analysed.

The result is shewn in the following table :—

Height Class.	Percentage of seedlings in the Twist classes.		Average Twist by factors.
	A1 A2 B.	C. D. E.	
10″ or less	78	22	1·76
10″ to 14″	61	39	2·82
Over 14″	42	58	4·32

It can be shewn numerically with the same data that good height growth *on the average*, implies a high degree of general vigour and of carrot development, and it is not considered necessary to introduce further complications to correct for this tendency also.

The effects of *coppicing* have been considered in Part I. (pp. 25-27), and will not be further discussed in this contribution. The effects of *over crowding* and of intense *competition with grass* or weeds are probably similar ; they have been the subject of a special set of experiments, but too few seedlings were obtained to yield conclusive results. It may first be noted that since both influences result in reduced carrot development, they would be expected to result also in a reduced average twist compared with seedlings of the same age not subject to them. The same considerations hold for the possible influence of strong overhead shade. At the same time, it has to be borne in mind that in all these cases, it is always possible that it may only be a matter of a delay in the time of appearance rather than a diminution in the total final amount of twist.

The experiments in Kumaon were abruptly ended by the incendiary fires which swept over the plantations. The data collected in Kaunli Garden at Dehra Dun at the end of 4 growing seasons are as follows. The unweeded plots carried a very dense growth of grass, and the seedlings were almost all unbranched ; it is recorded that a considerable percentage of the seedlings originally present were killed out by this weed growth. The seedlings of Plots 1, 9 and 11 were trampled* under foot at the beginning of the second growing season : they and the plants of the other weeded plots were healthy and vigorous, though a tendency to low branching with resultant bushy growth form was decidedly noticeable. Plots 5, 10 and 15 were laid out for an investigation into the

* The Sylviculturist cannot absolutely guarantee that this was done in accordance with the prescription. It is believed it was done, and in any case the figures are of interest as a control.

effects of growing with overhead shade, but almost all the seedlings died in the first year.

Origin of seed.	Plot No.	Treatment.	Number of plants.	Average Diameter. Ins.	Number free from twist.	Percentage	Average Factorial Twist.
Straight Locality Straight Trees.	6	Weeded, not worked	39	1·15	28	72	0·90
	7	Weeded and worked	38	1·3	25	66	1·37
	9	Weeded, Trampled	30	1·4	23	77	1·03
	8	Unweeded . .	20	2·0	19	95	0·30
Straight Locality, Twisted Trees.	11	Weeded, not worked	16	1·4	10	62	1·06
	12	Weeded and worked	21	1·5	9	43	2·80
	13	Weeded, Trampled	9	1·9	4	14	2·33
	13	Unweeded . .	6	1·3	4	67	1·12
Twisted Locality, Twisted Trees.	1	Weeded, not worked	35	1·0	14	40	2·06
	2	Weeded and worked	33	1·3	7	21	3·20
	4	Weeded, Trampled	21	1·3	4	19	3·52
	3	Unweeded . .	17	0·7	8	48	2·18

Average factorial twist for the three types of seed origin for the four different treatment, are :—

Unweeded	1·20, diameter 1·3"
Soil weeded, not worked	1·34, ,, 1·2"
Soil weeded and worked	2·46, ,, 1·4"
Soil weeded and seedlings trampled	2·29, ,, 1·5"

That the lowest percentage of twist should be found in the rather drawn up seedlings grown undisturbed in dense grass, is in agreement with what was found in Kumaon. The marked difference between the two weeded plots in one of which the soil was also worked is rather unexpected, and would appear to be attributable to the greater vigour of the plants, (*cf. supra* p. 17 and the greater average diameter) but quite possibly to the small number of plants. The figures for the trampled plots can only be explained, again apart from ascribing their peculiarities to the small number of plants examined, as indicating that the trampling has no more effect on the percentage of twist than has the working of the soil, or that the latter operation itself involved a certain amount of trampling, which is by no means unlikely.

The appearance of appreciable proportions of R twist in the 3 and 4 season-old plants was unexpected in view of its complete absence in the 2-season-old seedlings and in natural seedlings, though the results from the girdling experiments will be remembered. It is conspicuous in the Nainital seedlings including more than half the total number of twisted stems found, and this in most twist grades. The sowings of straight locality seed in Khabdoli give similar results, but in all the remaining sets, R-twist is confined to the A2 grade and so is perhaps of minor importance. Of the 1,227 plants examined 449 or 36 per cent. shew more or less twist and of these 97 or 22 per cent. have R-twist,

or excluding the A2 class for both R and L twist, only 12 per cent. Detailed examination shows that exclusion or cancellation of R-twist does not affect the qualitative results and so the course mentioned on p. 46 is adopted.

8. Statistics Concerning Inheritance.

In the foregoing paragraphs, certain factors have been considered which might vitiate the results of the examination of the seedlings of known origin, in so far as these are to form the basis of deductions as to the possible inheritance of twisted fibre. The following points have been established in this connection.

(i) Seedlings of less than average vigour should be excluded.
(ii) Minor injuries to the stem are unimportant.
(iii) The absence of a straight unbranched taproot is unimportant.
(iv) It is advisable to use the " carrot "grades in equal proportions in each set as a connection exists between " carrot " formation and twist ; such equality already exists to a sufficient degree in the field data.
(v) It is essential that the seedlings compared are of the same age.
(vi) Provided a sufficiency of seedlings is used, results of parallel experiments agree well *inter se* : with 100 seedlings, the percentages should not vary more than about 5 per cent. on either side of the mean.
(vii) Variations in other factors such as height, density, etc., are sufficiently allowed for under the adjustments for vigour and carrot formation with which they are connected.
(viii) It is probably best to ignore a right-handed twist, counting the affected seedling as straight.

Dealt with in this way, the field data may be presented in tabular form, separately for the 2-season and the 4-season-old seedlings and 2-season-old coppice shoots of 6-season-old plants, figures from the Khabdoli (K. S.) sowings being in every case entered next to those for the parallel sowing in Maharpali (M) : it need only be noted that since the numbers dealt with in the latter place were much higher, the percentage results should be more reliable than for Khabdoli. The figures from Sarna are omitted as being based on relatively small numbers of plants, but they are in close agreement with those from the two localities given. The figures from Dehra Dun for 4-season-old seedlings are given on p. 57 and may be compared with those in the following table.

2-season-old seedlings : Sown in 1917 : Examined in 1919.

Series.	Origin of Seed.	NUMBER OF SEEDLINGS.				PERCENTAGE IN EACH TWIST CLASS.												Average twist on factorial system.		
		Examined.		Accepted.		A1		A2		B		C		D		E				
		M	KS	M	KS	M	KS	M	KS	M	KS	M	KS	M	KS	M	KS	M	KS	Both
1A	Nainital N .	400	110	251	106	50	55	19	9	14	14	10	6	6	9	1	7	1·31	1·71	1·37
1B	Nainital G .	550	..	499	..	60	..	12	..	15	..	6	..	6	..	1	..	1·10	..	
2	"Straight" Locality. Straight Trees .	626	105	520	103	41	45	16	16	19	24	9	1	11	13	4	1	1·88	1·54	1·71
3	"Straight" Locality. Twisted Trees .	100	110	96	105	38	20	7	11	16	22	12	6	19	23	8	18	2·95	3·61	3·28
4	"Twisted" Locality Straight Trees .	130	102	113	100	29	36	11	12	10	13	17	13	21	14	12	12	3·21	2·70	2·9
5	"Twisted" Locality. Twisted Trees .	365	104	315	103	16	19	10	9	16	19	10	9	39	21	9	23	3·88	3·95	3·90

4-season-old seedlings : Sown in 1917 : Examined in 1921.

Series.	Origin of Seed.	Number of seedlings: Examined M	Examined KS	Accepted M	Accepted KS	Percentage in each twist class: A1 M	A1 KS	A2 M	A2 KS	B M	B KS	C M	C KS	D M	D KS	E M	E KS	Average twist on factorial system: M	KS	Both Plots.
1A	Nainital N.	127	161	122	156	89	96	3	1	3	1	3	0	2	2	0	0	0·33	0·15	0·22
1B	Nainital G.	160	.	159	.	91	.	6	.	1	.	1	..	1	..	0	..	0·18	..	
2	"Straight" Locality. Straight Trees	125	127	122	118	77	82	3	3	5	3	6	2	6	10	3	0	0·97	0·77	0·87
3	"Straight" Locality. Twisted Trees	100	89	97	82	47	75	4	5	12	0	5	7	27	11	5	2	2·50	1·15	1·82
4	"Twisted" Locality. Straight Trees	100	12	96	12	54	67	10	8	12	0	1	8	21	8	2	9	1·80	1·60	1·70
5	"Twisted" Locality. Twisted Trees	157	98	151	90	40	49	7	5	3	3	13	11	35	30	2	2	2·91	2·51	2·71

NOTE.—Series 4, based on 12 seedlings only, is included for sake of completeness; it is of minimum value.

Two-season-old Coppice Shoots : Sown 1917 : Coppiced 1921 : Examined 1923.

Series.	Origin of Seed	Number of Shoots Examined		Percentage in each Twist Class								Average twist on factorial system.		
				A and B		C		D		E				
		M	KS	M	KS	M	KS	M	KS	M	KS	M	KS	Both.
1A	Nainital N. . . .	109	163	93	98	4	1	2	1	0	0	0 26	0·04	0·18
1B	Nainital G. . . .	97		90		10		0		0		0 23		
2	" Straight " Locality . . Straight Trees . . .	84	158	85	91	6	5	8	4	1	0	0 93	0·49	0·72
3	" Straight " Locality Twisted Trees . .	64	139	58	77	17	8	25	15	0	0	2 12	1 13	1·63
4	" Twisted " Locality . Straight Trees . .	37	11	60	64	16	9	19	27	5	0	2 54	2 36	2 45
5	" Twisted " Locality . . Twisted Trees . . .	25	107	52	48	20	21	16	28	12	3	3 36	3·00	3 18

From the first two tables, it can be seen that the average twist as determined by the factorial method, is very similar in every case for seedlings of the same origin whether raised in Khabdoli or Maharpali: the agreement in the individual twist grades is also usually good considering the conditions of the investigation, and far outweighs the occasional discrepancies. For the 2-year seedlings the average for all five series is 2·62 in Maharpali and 2·69 in Khabdoli: for the 4-year seedlings the figures are 1·69 and 1·24 respectively, the Khabdoli figures being lower throughout, but very slightly so except in series 3. It is accordingly taken as established that the conditions responsible for the fact that the existing forest at the Khabdoli site is predominantly straight-fibred, whilst that at Maharpali is intensely twisted, do not appreciably affect the young seedlings grown under protection from external injurious agencies. As regards the difference in the result obtained after two and four growing seasons, it will be noted that despite irregularity in series 3 and 4, the order is the same, and the difference in each case is very close to 1·2 units. If this amount be deducted from the averages for the younger plants, a very close agreement is recognisable, the figures becoming:

After 2 seasons . .	0·17	0·51	2·08	1·75	2·70
After 4 seasons . .	0·22	0·87	1·82	1·70	2·71

There is accordingly no danger of obscuring results or introducing new errors by an amalgamation of the two tables, and this process will facilitate a comprehension of the results of the investigations under discussion and the drawing of final deductions. The following table accordingly shews for the seedlings of five different origins, (*a*) the average degree of twist on the factorial method (which represents a combination of the chances of a given seedling being twisted, and the degree of the

Series	Origin of Seed.	Average Percentages in the Twist Classes.			Average Twist on factorial system.
		A1	A+B	C+D +E.	
1	Nainital	73	90	6	0·80
2	"Straight" Locality Straight Trees. . . .	61	84	11	1·29
3	"Straight" Locality Twisted Trees. . . .	45	64	28	2·55
4	"Twisted" Locality Straight Trees. . . .	46	65	25	2·32
5	"Twisted" Locality Twisted Trees. . . .	30	49	40	3·30

twist when present), (*b*) the percentage of A1 seedlings entirely free from left-handed twist, (*c*) the percentage of A+B seedlings free from twist in the stem proper, and (*d*) the percentage of C+D+E seedlings with left-handed twist quite pronounced in the stem.

9. Deductions from Statistics.

From the last table given above representing the results of an examination of 2,700 seedlings of known origin, the following deductions may be made.

(i) Seedlings from seed free from L twist from either parent (Nainital) show a low but appreciable percentage of twist when grown in areas where twisted fibre is not infrequent.

(ii) Seedlings from seed whose carpellary parent is straight and very probably of pure straight descent, and whose pollen parent is probably of similar type but may sometimes be twisted (*i.e.*, from straight trees in a "straight" locality), have a percentage of twist appreciably higher than seedlings of pure origin, but still quite low, approximately 13 per cent. shewing twist after 4 seasons.

(iii) Seedlings from seed whose carpellary parent is twisted and very probably of twisted descent, and whose pollen parent is probably of similar type but may sometimes be straight (*i.e.*, seed from twisted trees in a "twisted" locality), have a high percentage of twist, about four times as great as that of the opposite type. Approximately one-half of the seedlings shew twist after 4 seasons

(iv) Seed of mixed origin give intermediate results.

These may be summarised to the effect that *twist in the parent tree is definitely inherited in the seedling,* whether either parent is twisted or both are. To them must be added the following, which if of less importance, are also of significance in a consideration of the matter in its wider aspects.

(v) No twist is visible in seedlings of 1 season only.

(vi) No right-handed twist is found in 2-season-old plants but occurs to a small percentage of all lots of 4-season-old plants.

(vii) The percentage of twist found is appreciably greater at the end of the second season, than after the third and fourth—this being in contrast to what is found with natural seedlings growing in areas open to grazing, etc.

(viii) If right-handed twist be cancelled against an equal amount of left-handed, the seedlings of pure straight origin, appear free from twist after four seasons' growth : a similar adjustment does not greatly alter the figures for seedlings of the other origins.

(ix) Seedlings from twisted trees in a " straight " locality and those from straight trees in a " twisted " locality, give approximately equal results but with a wide range of variation.

(x) The inheritance is demonstrated for plants up to an age of six growth seasons (*cf.*, p. 54) and equally for two-season-old coppice shoots on six-season-old stocks as apparent from the table on p. 61.

10. **Theoretical Considerations.**

ORIGIN BY MUTATION.

The decision having been reached that the occurrence of twisted fibre is a peculiarity which can be passed on to a tree's offspring, the question arises as to the mechanism of this inheritance. Can it be compared for example with any of the better understood cases of " Mendelian " inheritance ? In the light of what has been written in Part I, it might be thought that the tendency to twist is of the nature of a loss-mutation, the loss being that of a controlling factor which normally keeps the tissue elements in the " straight " orientation. To allow for the appearance of occasional twisted seedlings from homozygous straight seed and the converse case, it is also necessary to postulate development or an inhibitive factor. It is indeed a simple matter to account for the figures obtained in any of these experiments making assumptions as the proportions of homozygous and heterozygous parentage, but no definite light can be thrown on the problem without careful experiments through 2 or 3 generations of trees of known origin– which is as good as impossible at present.

There are further difficulties, three of which have been mentioned already—the change in the percentage of twist with the age of the seedlings, the probabiiity that a certain, if small, proportion of seedlings from seed free from all hereditary taint may be right or left twisted, and lastly that it seems almost certain that external influences affecting the seedlings are of considerable importance in the development of twist even if a tendency to it is already present as an hereditary factor.

For the present, it seems most satisfactory to suppose that a tendency to twist is present as a heritable constitutional factor in many trees in the forests supplying the seed for these experiments. Under equal conditions, the tendency finds expression in the seedlings proportionately to the total of twist in the parents of the seed, but under ordinary forest conditions this condition is liable to be obscured by local influences which may greatly increase the proportion of visibly affected seedlings and the intensity of the defect. It may also be noted that some

of the facts suggest comparison with what has been termed "Mass mutation" in *Œnothera* and other plants, for the origin of the twisted variety from the type form. If a mutation is really in question, it must be a very simple one (hence the suggestion of mutation by loss) since the facts are such as to force the conclusion that it has occurred independently in several localities where a particular set of conditions prevail, these localities being scattered over a large tract of country.

TWIST AS AN "ACQUIRED CHARACTER."

There is a simple alternative explanation of the facts if the doctrine of the inheritance of acquired characters is accepted. It is then only necessary to admit that the twisted condition of existing crops is the direct result of the conditions under which they have grown up, and that their peculiarity is passed on to their off-spring even if grown under a different set of conditions excluding those responsible for the development of twisted fibre. There is however one serious difficulty, and that is to demonstrate that twisted fibre can be considered as an acquired character. It is clearly established that in Kumaon a connection exists between a certain set of conditions, generally to be summed up as proximity to a centre of population, and an abnormal proportion of twisted trees, but precisely the same conditions elsewhere do not produce the same result : even in Kumaon striking exceptions to this generalisation can be found. No precise data are available, moreover, to indicate that the connection is in any way directly causative, or if it be accepted to be so, then how. The writer's view is that the facts quoted are better co-ordinated by the supposition that the important effect of the population is rather its unconscious selection of twisted trees for survival and reproduction, than the causation of twisted fibre in the individual plants -and it is on these grounds that mutational hypothesis is at least tentatively preferred.

11. **Summary and Conclusions.**

The deductions which have been made from the experimental data collected have been given in detail in the several sections above, but for ready reference it is advisable to collect them in a condensed form.

Experimental Basis.—A detailed examination of a total of over 6,000 seedlings at ages of 1 (about 400), 2 (2,700), 3 (453), 4 (1,545) and 6 (1,170 including 1,118 coppice shoots) seasons, derived from seed of known origin as regards the cone-parent and probable pollen parent, of five types, repeated in 4 (mainly in two) localities in one of which twist is intensely developed in the existing crop and in another is relatively infrequent.

Statistical Results.—(i) Virtually the same results are obtained in all localities after 2 and 4 seasons' growth, and in 2-season-old coppice shoots.

(ii) Twisted fibre is practically never developed during the first season of growth, appears abruptly in the second season, and under the conditions of the experiments appears to decrease again in the 3rd and 4th seasons.

(iii) R-twisted fibre is not found in 1 and 2-season-old plants but does occur to a small but appreciable extent in the 4th season in the seed of all origins, and also in the only case examined in the 3rd season.

(iv) Seedlings from an origin presumably untainted by twist, are after 4 seasons' growth, virtually free from twist, having only 3 per cent. L-twisted in the stem,* and nearly the same R-twisted—this although, 18 per cent. were found to be L-twisted after the first two seasons. The same applies to their 2-season-old coppice shoots.

(v) Seed from twisted parents gives seedlings exhibiting a high percentage of L-twist in the stem, 56 per cent. after two, and 47 per cent. after four seasons.

(vi) Ordinary injuries or defects in the stem or root of seedling of one season do not appear to influence the development of twist in the following year, but R and L twisted fibre in equal proportions appears in the woody swelling of the hypocotyl caused by girdling the lower part of the latter.

(vii) In a given sowing, the more vigorous plants and those with considerable carrot-development, shew a higher percentage of twist than the remainder.

* NOTE.—Twist classes C, D and E are included here.

CONCLUSIONS.

(i) It is a character common to all trees to produce a varying but small proportion of individuals with twisted fibre, the twist being L at first but changing to R with passage of a period of time varying greatly in length with the species. These characteristics are best developed in coniferous species.

(ii) There is probably a certain amount of fluctuating variation in the direction of the fibre accounting for occasional exceptions to this general rule, others being perhaps traceable to special inhibitive influences.

(iii) In areas where twist is exceptionally frequent, twisted fibre, or a tendency to produce it, is unquestionably capable of being transmitted from one tree generation to the next.

(iv) Conditions found in existing forests make the inheritance of twist as an acquired character difficult to accept as a satisfactory explanation.

(v) In such areas, a twisted variety may have originated, possibly by a simple loss mutation of a factor controlling the orientation of the growing cells. Such mutation must have originated independently in many localities, its survival being favoured by the continued selection of the straighter trees foı removal.

(vi) Sound forest management on the generally accepted lines especially as regards seed-selection and thinning, should result in time in the elimination of twisted trees.

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Blanford :—*Taungya* in Burma. Plate I.

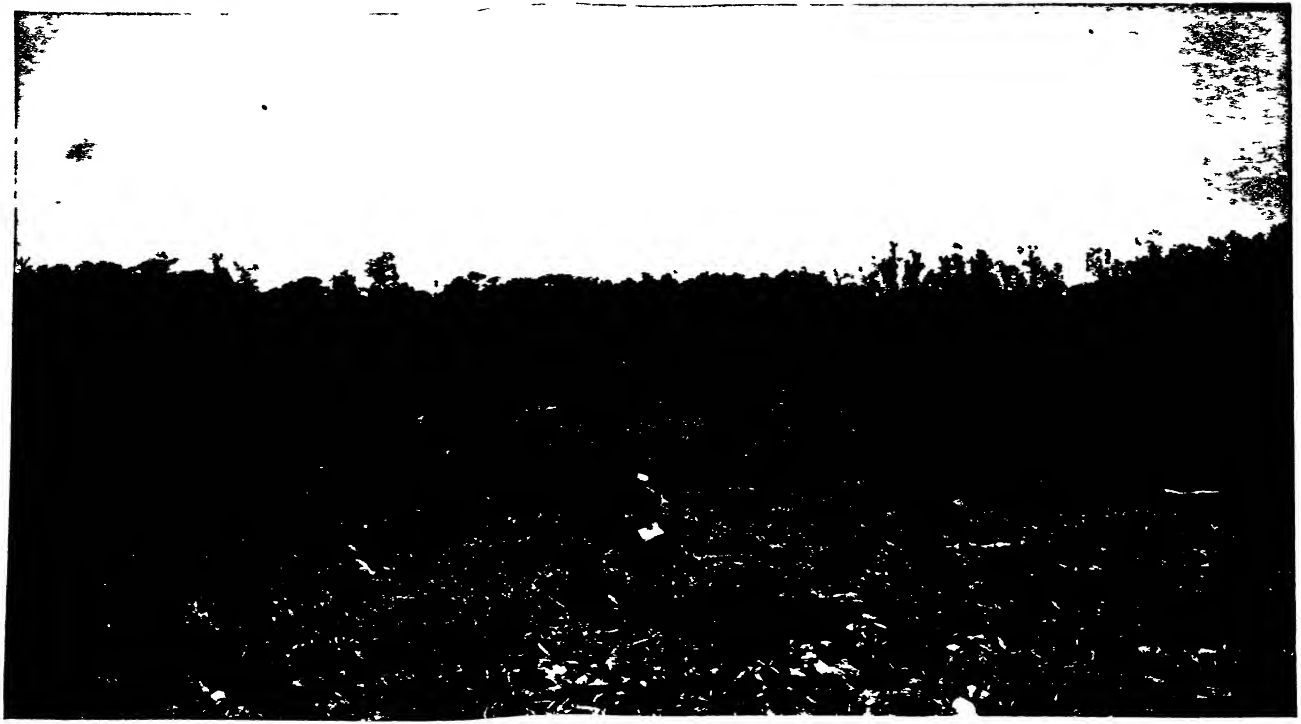

Photo of a *taungya* taken in June. Well cleared of all marketable timber. Maize and paddy have been sown. In the background a 20-year old teak plantation, that on the right having been somewhat damaged when the *taungya* was burnt. Stakes at which teak seed has been sown can be distinguished in foreground.

INDIAN FOREST RECORDS

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REGENERATION WITH THE ASSISTANCE OF *TAUNGYA* IN BURMA.

CHAPTER I.—INTRODUCTORY.

1. Foreword.

The object of this note is to summarise the more recent experience in regeneration with the assistance of *taungya* cutting in Burma. It is hoped that the note may be useful to Forest Officers in Burma, but mainly it has been written with a view to describing the work to Indian and other Forest Officers, who may find points in the Burma methods that can be adapted in the solution of their own regeneration problems.

2. Definition of the term *taungya*.

Taungya is the Burmese name for temporary cultivation on hill land. The word is derived from "*Taung*" - a hill and "*Ya*"=cultivation, usually of a temporary character. A *taungya* cutter is one who cuts and cultivates a *taungya*. Regeneration of forest species with the assistance of *taungya* is similar to the well known German system of "*Waldfeldbau*" or cultivation of forest with field crops.

3. Brief description of the method.

Exploitation of the forest crop is carried out by the clear felling method. All marketable timber is extracted. In the typical bamboo forests of Burma there remains the bamboo undergrowth and a number of worthless trees for which there is no demand. The *taungya* cutter fells the growth on the land and burns it during the hot weather. During the rains he sows rice or other cereals together with a few vegetables. Cultivation of the soil is not usual in the ordinary type of *taungyas*. Sowing or planting of tree species is carried out with the sowing of the field crop, and the tree seedlings are tended by the *taungya* cutter as

long as the field crop is on the ground. As soon as the crop has been reaped the land is taken over by the Forest Department and the tree seedlings are tended until the crop is established.

4. Past History.

Regeneration of teak with the assistance of *taungya* is no new thing in Burma. Sir William Schlich states that about June 1867, very shortly after his arrival in Burma, he was shown a teak *taungya* plantation in the Kabaung forests of the Toungoo Division which he believes to have been then in its second year. This would place the earliest *taungya* plantation about the year 1866. Mr. Grahame was D. F. O., Toungoo, at that time and Col. Seaton, to whom the credit for originating *taungya* plantations is generally given, was then Conservator. *Taungya* plantations were probably commenced in the Tharrawaddy Division about the same year, previous plantations having been made on the regular method. One of the first *taungyas* was made by a Karen, U Pan Hle, in Tharrawaddy Division, as a personal present to Sir Dietrich Brandis. The method spread rapidly and in the eighties and nineties large areas were planted in many parts of Lower Burma. Early in the twentieth century, however, it was found that teak plantations had been scattered about in such an indiscriminate way, in small blocks all over the forest, that organised tending and thinning were almost impossible and for some time there was a great prejudice against any further planting operations. The reason for the scattering of plantations all over the forest was mainly the fear of making plantations on land which was already under teak forest. In this way many of the plantations were made on soil which was not suitable for teak and it is due to this and to the fact that early tending and thinning were neglected that so many of our older plantations are so disappointing. Nevertheless, the very large area of old plantations (75,517 acres up to 30th of June 1910) form a very valuable reserve of stock and will undoubtedly materially increase the outturn of teak when they come to maturity.

From 1906 on, *taungya* plantations were almost given up in most Burma Divisions and attention was turned more to the improvement of the natural stock by means of improvement fellings (*i.e.* the eradication of useless species, bamboos and *ficus*-bound trees together with climber cutting, in the interests of the more valuable species).

It is unnecessary here to trace the evolution of improvement fellings. The eventual result was that the type of felling, which dealt with the younger age classes and which was called 'Y' felling, gradually came to be a very heavy felling, approximating to a regeneration felling and

in some cases, as for instance at Putkya in N. Toungoo Division, was actually a seeding felling, *i.e.* clear felling of all but seed-bearers with the object of inducing natural regeneration. The cost of such fellings was high and as long as the results depended on natural reproduction they were extremely uncertain. Nevertheless the value of improvement fellings, apart from the inducement of regeneration, should not be underestimated, more especially in forest which will continue to be worked under the selection system, for many years to come a very large proportion of the total area. This note deals, however, with the more accessible forests in which the introduction of the uniform method with clear felling opened out the way for the re-introduction of *taungya* plantations which had always proved to be the cheapest and most successful method of regeneration yet tried. A new era may be said to have started in 1918 with the commencement of regeneration under the working plan for the Tharrawaddy Yoma forests. This working plan prescribed exploitation by clear felling, in coupes in convenient situations, followed by regeneration over $\frac{1}{R}$th of the area considered suitable ; the rotation (R) being fixed at 120 years. The methods adopted in Tharrawaddy Division rapidly spread, though the unsystematic manner in which the work was commenced in many divisions, without arrangements for exploitation of the crop, in areas difficult of access and often unsuitable for the method adopted, have in many cases brought the method into disrepute ; nevertheless the resumption of *taungyas* was a great step forward in Burma towards systematic Forestry and, where thorough exploitation of the timber is possible, only requires to be properly organised to hold its own.

CHAPTER II.—CIRCUMSTANCES AND LOCALITIES SUITABLE FOR THE INTRODUCTION OF CLEAR FELLING FOLLOWED BY REGENERATION WITH *TAUNGYAS*.

1. Brief description of the forests of Burma.

The forests of Burma cover very large areas and are of great potential value. The great bulk of them is, however, characterised, by a dense growth of bamboos and a very sparse stocking of trees. Moreover the different kinds of trees are rarely if ever found pure but are scattered here and there all over the forest. The forests of the Pegu Yomas may be given as an instance. They form by far the largest and most valuable stretch of forests in Burma covering 6,539 sq. miles. Yet it is estimated that in these forests there are, on an average, only about 17 trees over 3′ girth to the acre and of these only 13 per cent. are teak, 19 per cent. are *pyinkado* (*Xylia dolabriformis*), the next most valuable species, and no other species exceeds 3 per cent. This sparse stocking, together with the ease with which the most valuable timber, teak, can be extracted by floating, has no doubt contributed to the lack of progress in communications within the forest, which renders so large an area still inaccessible to the exploitation of any timber but teak.

2. System of working suitable for the forests.

From the preceding paragraph it will be seen that clear felling and exploitation of all timber is not only unpractical over the greater part of the forests at present but that, owing to the vast area of the forests and the difficult nature of the country, combined with the very small stock of timber per acre, this system is hardly ever likely to be possible economically over large areas. Teak can, however, be floated out successfully from practically everywhere and is the only valuable timber which can thus be exploited. In the less accessible forests, therefore, selection for teak is the only possible method of working and cleanings and thinnings (improvement fellings), in favour of teak the only possible silvicultural work, though plantations of teak in the less accessible forests can be justified. The more accessible forests comprise those which can now be exploited for hardwoods other than teak owing to the presence of roads or other means of communication and those forests which will undoubtedly become exploitable by the extension of communications within a reasonable time. These forests will be worked under clear felling followed by regeneration with *taungyas*.

3. The Working Plan.

Working plans are now made for whole divisions, dividing the forest into different working circles according to their accessibility, and the object for which they are to be managed. The following working circles are usually laid out :—

A. Forests inaccessible to extraction of non-floatable timbers to be worked under the selection system for teak. This forms the Selection Working Circle.

B. Forests now accessible or likely to become accessible to extraction of timbers other than teak within a reasonable time, to be worked under the clear felling system with regeneration by *taungyas*, for one or more of the following :—

1. Village supply (including supply of rightholders).
2. Local sawmill and local trader's supply.
3. Export supply, *i.e.*, not required for local consumption.

The last two often overlap and it is only in the case of a lease to a large firm that it is necessary to form a special export working circle. Ordinarily, extraction both for local supply and for export may be carried out by local traders working under short-term purchase contracts and there is no necessity to split off a separate Export Working Circle.

(i) THE VILLAGE SUPPLY WORKING CIRCLE.

It is first of all necessary to set aside small felling series in close proximity to the villages to be worked on a short rotation for the supply mainly of houseposts, bamboos and firewood. These felling series are usually situated in isolated blocks of reserved forests in the plains or on the edge of the main jungle. The annual regeneration area is small and, provided the areas can be regenerated by *taungyas*, regeneration presents little difficulty except where the areas are badly drained, as is frequently the case in blocks of forests situated in the middle of rice land. Exploitation may be carried out by the villagers themselves, often under licenses for small amounts sold by local license vendors who receive a commission on all revenue collected by them.

(ii) THE LOCAL SAWMILL AND EXPORT SUPPLY WORKING CIRCLES.

The outlines of the scheme of working accessible forests other than for village supply vary considerably and it may be of interest to deal somewhat fully with this subject as it very materially affects the question of regeneration.

(*a*) *Forests leased for exploitation of hardwoods for export.*

In the first place there is the scheme for exploitation that has to be adapted to a big hardwood-lease, the annual felling area of which may amount to 1,500 or 2,000 acres in one block. At one time the tendency was to give these leases wherever possible. They necessitated a large expenditure of capital on extraction routes and this in its turn necessitated a large annual felling area in order to provide the yield to pay a profit on the capital investment. It must be remembered that in Burma the majority of our forests do not contain a yield per acre of more than 10 to 15 tons of timber other than teak. Even with teak the yield will very rarely be as much as 20 tons per acre. Many of the big leases proposed have fallen through. The necessity for concentrating regeneration on such large areas proved to be almost impossible, owing to the great concentration of labour necessary and, in view of the rapidity with which the ground had to be covered, the constant shifting of the labour force. In the one lease that is actually working and where the annual felling coupe will be about 1,500 acres it has been decided that the felling of the teak, (not included in the hardwood-lease), and the regeneration will progress at a very much slower pace, the working circle being fixed only at a slightly larger area than is to be felled over under the 20-year lease for hardwoods. This has shown effectively the impossibility of regeneration keeping pace with extraction on a big scale. But indeed it is doubtful if extraction on this scale is really necessary for the exploitation of our hardwoods in the more accessible forests. The extension of communications has always led to the entrance of the small timber trader and the writer firmly believes that it is mainly in the extension of communications and the encouragement of the smaller trader that the future exploitation of these forests must rest. Big leases should be confined to areas which require considerable outlay of capital to render them accessible.

(*b*) *Forests accessible to extraction by local traders.*

The second case is where communications exist and where there is an established demand for timber. Such is the case in the Tharrawaddy, Zigon, North Toungoo and other divisions. In this case the scheme for exploitation must follow communications. Large coupes are not essential and small felling series with coupes of about 100 acres are convenient to manage and to regenerate. This is the ideal size for a regeneration unit as it can be worked by a village of 20 to 25 houses which would not be obliged to move its site too often.

(c) *Forests suitable for small long-term leases.*

The third case offers one of the most suitable solutions to the problem of exploitation. In Shwebo division two leases have been given for a series of small annual felling areas on condition that a small sawmill be erected in the jungle. There will then be a complete self-contained felling series worked for the mill and regenerated by the agency of a forest village. This seems to promise the best method of dealing with extraction. The immediate sawing up of many of our timbers, followed by seasoning in the plank or scantling, offers probably the best solution of the problem of the supply of timber in good marketable condition, while the problem of regeneration is very much simplified provided a forest village can be formed. The Working Circle may contain several of these felling series. It should be noted that it is not essential to lay out a complete felling series immediately. Provided always the total area exploited annually does not exceed $\frac{1}{R}$th of the working circle, the leased area may contain only sufficient annual coupes to carry on for the period of the lease and the felling series may be continued in some other part of the working circle after the completion of the lease.

(d) *Forests near settled* taungya-*cutting villages.*

The fourth case is somewhat different and deals more with areas in which there is little or no marketable timber. Often in these places there are already existing villages which have in the past cut *taungyas* all round the village and so reduced the forest to what is known in Burma as "*ponzo,*" *i.e.*, the dense regrowth mostly of bamboos or useless species, which results from temporary cultivation. In these cases very often the village is more or less a fixture and the felling series is bounded by the area that can easily be worked from the village. The great danger in this case is that the area regenerated annually is too small to supply an economic exploitation unit in the future. The less accessible such an area is the more this danger increases. It would be reasonable to make a short line of communication to tap an annual felling area of say 50 acres giving say 2,500 tons per annum where it could not possibly pay to do so for an annual area of only 10 acres yielding say 500 tons. These factors must therefore be taken into consideration when drawing up any regular scheme for regeneration. Under this category comes also the case where there is a certain amount of timber on the area but which is at present inaccessible and is likely to remain inaccessible, or at any rate not likely to be economically exploitable for many years. This case must be treated with great caution. In certain cases it is obviously permissible to sacrifice the existing stock of timber which is never likely

to be of any value owing to the small yield per acre and to replace it with a completely stocked crop of high potential value, the presence of which would, in the future, justify an extension of communications to tap it. For it must be remembered that whereas a stocking of 10 to 15 tons per acre in an area not at present tapped by roads will probably never pay for the high capital cost of communications necessary to exploit it, a stocking of 50 tons per acre over a sufficiently large area per annum will of itself justify the outlay. It may be remarked in passing that here is the crux of the whole of our difficulty in exploitation in Burma. It is entirely a question of tonnage per acre. As already stated we are handicapped by the difficulty that the majority of our forests will not, in their present state, yield more than 15 tons per acre.

4. Areas suitable for *taungyas*.

In the first place it is necessary to have a fairly dense crop of bamboo or useless growth to cut down and burn. The first essential to success is a successful fire and this is only possible if there is sufficient inflammable material left over after the extraction of all marketable timber. The dense bamboo so typical of the great majority of our teak forests is ideal but *taungyas* can also be cut in ever-green forest or in any forest where the soil is good and the material left for burning is sufficient to produce a good fire. At the same time in parts of the Province, especially in the Shan States, *taungya* cutters are content with a comparatively little growth to burn but this usually necessitates considerable cultivation of the soil, work which the ordinary *taungya* cutter would not usually undertake. The second condition is of course the presence of the *taungya* cutter. Either *taungya* cutters must be available and willing to work or else efforts must be made to introduce *taungya* cutters when a regular scheme for regeneration has been drawn up. The methods of *taungya* cutters differ somewhat in different parts of the Province and the adaptation of the regeneration methods to the local customs is one of the first points to be studied.

CHAPTER III.—MEASURES PRELIMINARY TO REGENERATION.

NOTE.—For the work described in this and following chapters, a typical programme of work showing the sequence of the various operations will be found in the appendix.

1. The exploitation *cum* regeneration plan.

The working plan lays down areas to be exploited and regenerated during the first period. It is usually left to the local officer to draw up schemes for exploitation and regeneration of the annual coupes. In forests where teak is present, *i.e* , in the majority of forests to be worked under these methods, it is necessary to take early steps to girdle the teak. Teak has to be girdled 3 years before felling to allow it to season and a further two to four years should whenever possible be allowed for the extraction of all teak and other timbers. In this connection it should be noted that girdling of other species can be done just as conveniently as of teak and in the case of *pyinkado* (*Xylia dolabriformis*), certainly and probably of certain other species, girdling will improve the quality of the timber most appreciably. Further research into this question of seasoning by girdling is desirable but the possibility of carrying out the girdling of other species as of teak must not be lost sight of. It will be seen from the above that it is necessary to prepare for the exploitation of each coupe 5 to 7 years before regeneration. It will not, of course, always be necessary to carry out the girdling of each annual coupe exactly the same period ahead. It will probably be found more convenient to girdle over a convenient area such as a compartment, containing possibly three or four annual coupes, at one time.

At the start of a new working plan, however, it is not usually desirable to wait 7 years before commencing to do any regeneration at all. It is necessary to make a small beginning both to train subordinates and to organize the labour necessary for the work. This can only be done slowly. Efforts can therefore be made to commence regeneration immediately on a small scale, either by taking up an area devoid of marketable timber or by arranging for the early extraction of suitable areas the teak being extracted green where necessary or if preferable can be left girdled for extraction later. As a general rule the early completion of extraction before regeneration must be insisted on. The rush to complete extraction at the last moment causes delay and annoyance to the *taungya* cutters and has resulted over and over again in a late and incomplete fire and a partial failure of the regeneration or, on the other hand, in the waste of valuable timber when burning the *taungya*. It is

far better to leave any timber that cannot be extracted standing, provided it is not removed until the young regeneration is firmly rooted and extraction is confined to the hot weather when the ground is hard. Little permanent damage is then done. This should, however, only be permitted in exceptional circumstances.

Having laid down the annual coupes for exploitation and regeneration a scheme showing the years in which each operation must be carried out is drawn up for each coupe. The following operations are necessary in the order named :—

1. Stock mapping and laying down the lines on which regeneration should be carried out including the choice of species for the future crop.

2. Girdling of all teak and, if considered suitable, of other hardwoods which can be killed by girdling.

3. Extraction of teak 3 years after girdling followed by extraction of other timber.

4. Regeneration.

2. The regeneration plan based on the stock map.

In the past the choice of species and the plan for regeneration has too often been left until just before regeneration when most of the original stock has been extracted. The main indication of the suitability of the area for each species has then depended on an examination of the soil and subsidiary growth, more especially of bamboos. At present our knowledge of soils is very meagre and it has been impossible to standardise the various classes of locality suitable for the different species. Many mistakes have been made. It has now been realized that the best indication of the species most suitable is the actual tree growth existing on the area before extraction. Hence the necessity for a careful study of each coupe before extraction and this is most conveniently carried out either at the time of girdling or shortly before girdling is due. It has now been prescribed that no preparations for regeneration shall be commenced before a careful regeneration plan has been drawn up. The actual lines on which this examination should be carried out have yet to be determined but there can be little doubt that a careful stock map, indicating the class of forest, must be supplemented by height measurements of the more valuable species growing on each soil class. In many of our forests the soil varies within very short distances, so that a species indicated by height as the most suitable for one area may be entirely unsuitable for planting on an adjacent area even under 100 yards away.

It will thus be realized with what care and detail this examination must be carried out.

Areas unsuitable for regeneration because of the low productive quality of the soil must be carefully marked out as it is essential to restrict regeneration to soil on which a profitable crop can be raised. Areas covered with a good stocking of young trees of valuable species should also be carefully entered on the stock maps as girdling and extraction of the timber must in such areas be limited to mature trees only. All trees on such areas that can remain for a further rotation should be left. Only well stocked patches of reproduction or pole growth over at least half an acre in extent need be recorded. These should be carefully preserved and not cut over when regenerating the rest of the area. It has been found in practice that areas of under half an acre are not worth retaining. Indeed, in the writer's opinion, areas of under one acre are of little importance as the tendency always is for small patches such as these to diminish very greatly in size. In the first place it is impossible entirely to prevent the encroachment of the *taungya* fire into them and in the second place small patches merely serve as an interruption of the crop, the effect of which is usually considerably greater than might be expected from the actual area of the patch. In the case of small well established patches of reproduction of such fire hardy species as teak it is safe to ignore them as the reproduction from coppice shoots after the fire can be relied on to replace the original growth.

3. Choice of Species.

We come now to the most thorny problem in connection with the regeneration. Opinion in Burma is sharply divided. One school favours teak being planted wherever it will grow on the score that it is by far the most valuable species and always will be in the greatest demand. The other school, which the writer favours, would insist primarily on the selection of species with strict regard to the soil and locality. Teak certainly must be grown extensively but only on the soil that is most suitable to its growth. The writer feels very strongly that teak is not and never can be the only timber likely to fulfil all the requirements of the timber market. However plentiful and cheap teak might be and however high the profits of planting teak, he cannot believe that the State is justified in producing teak on all localities on which teak can grow. Teak is an extremely hardy species. It will grow on practically every class of soil and even in its youth may show encouraging growth on soil that cannot in any way be considered suitable for its best growth. It is often therefore misleading. The best growth of teak requires a

well drained, well aerated sandy loam and it is on this type of soil that the planting of teak should be concentrated. The study of soils is however a branch of knowledge that has been very much neglected in Burma and not until we have been able to study the matter more fully shall we be able to classify the soils and state more fully the requirements of each species. For the present our best indication of the species to be grown *is a careful examination of the* previous stock.

There are so many species other than teak which have claims to our consideration that it is extremely difficult at first to make a choice. Mr. Bourne in his Working Plan for the Nilambur Forests of Malabar tackles this question on very sound lines and the author proposes to follow his example. In the first place the choice should be confined to species indigenous in the actual forest area under consideration. If teak is one of these then teak must certainly be the first choice. In the second place the relative value of the species must be considered and in this connection it should be noted that relative value is not indicated by value per ton but must also depend on rapidity of growth and money return per acre, allowing for the length of rotation necessary. In the third place it is useless to plant small areas with a number of different species. Sufficient of each species to supply an industry or market demand based on that species is necessary and the plantations of each species must, as far as the variation of the locality permits, be concentrated sufficiently to allow exploitation to be as economical as possible. Bearing these main points in mind the final selection of the species must be based on the soil and locality, the growth of each species in the original stock being taken to indicate the quality of the locality and the most valuable species capable of growing at least over the average quality being selected.

4. Fire protection.

The advantages of fire protection as a measure preliminary to regeneration are that it serves to enrich the soil, to preserve the cover and most important to conserve all inflammable material against the year in which the *taungya* is cut. The advantages of a good burn in the year of regeneration are so important that any steps to ensure that success are justifiable. Before regeneration there must be a considerable removal of cover by extraction and a very great collection of the debris of felling. Fires after or during extraction will naturally be fierce and will render the growth much thinner and encourage the entry of weeds and grass. All this tends to increase the difficulty of a good burn before regeneration and also seems to prevent that tremendous stimulus to growth that follows a successful fire. Moreover the establishment of grass and weeds

before regeneration is certain to lead to trouble. The writer very strongly recommends therefore a short period of 3 to 5 years of fire protection before regeneration. At the same time it must be remembered that it is just during this period that extraction is being carried out and the institution of fire protection is often a very serious hindrance and annoyance to the extraction agency. If in practice the results of burning before regeneration are found to be very serious and fire protection is not found to be compatible with successful extraction it might almost be desirable to fire protect for about 3 years after the completion of extraction before regeneration is commenced. It is not thought, however, that this will usually be necessary.

5. Forest Villages.

It is not intended here to enter into the organization of Forest Villages as practised in Burma. Our organization is as yet in the making and the problem must be tackled in each case according to the local circumstances. One point is however important. The size of the village must be fixed by the size of the regeneration area. The area worked by *taungya* cutters in different parts of the Province varies considerably and sometimes the cultivation is carried on for two or even more years, instead of the usual one. It is necessary therefore to find out the average annual area that each *taungya* cutter is capable of doing and on that to base the size of the village required. In Tharrawaddy division for instance the average may be taken at between three and four acres per household. Good *taungya* cutters with male help in the shape of adult sons can manage as much as six, but a family, consisting of a man and his wife only, cannot usually cultivate efficiently more than 3 or 3½ acres. It is therefore necessary to have a village of 25 to 30 houses to regenerate 100 acres a year. The villagers are given free building materials, free land for *taungya* cultivation and are sometimes let off all taxes. In addition the headman usually receives some regular payment and the *taungya* cutters are paid by the results of the regeneration in their *taungyas*. Advances for purchase of food, seed, rice, etc., have to be given to them when first they enter a village or when they have had bad crops. When they are free from the *taungya* work they are employed on forest work for which they get the ordinary rates of pay.

6. Final regeneration plan.

The plan for regeneration with map laying down the actual areas to be planted with each species and based on the original stock-map and regeneration plan must be brought up to date and sanctioned by the competent authority before October 31st in the year before regeneration.

7. Allotment of areas to *taungya* cutters.

It has been found that if *taungya* cutters are allowed to select their own areas there are always narrow strips of jungle left unfelled between their *taungyas*. Moreover they have no idea of area and must be prevented from taking in too large an area which they would not be able to manage. It has, therefore, been found necessary to apportion the area to the different *taungya* cutters so that no one gets more than he can manage. As soon as the capabilities of each *taungya* cutter are known the area can be varied for each man according to the amount he is able to do. All this work must be carried out so that the *taungya* cutter can start his work early. Ordinarily each *taungya* cutter should have his area allotted and be ready to commence felling before the end of January.

CHAPTER IV.—DESCRIPTION OF THE WORK ORDINARILY CARRIED OUT BY THE TAUNGYA CUTTER.

Before dealing with the regeneration of tree species in *taungya* it will perhaps be as well to outline the work done by an ordinary *taungya* cutter in the cultivation of his crop. Felling of the forest growth left after extraction is usually commenced early in February. In bamboo jungle all the bamboos and low undergrowth are felled first and any trees which may have been left from the extraction, because they are not marketable, are felled after the bamboos. The object of this is to lay the bamboos as flat on the ground as possible. Unless this is done it is almost impossible to get a complete burning and this leads to a lot more work afterwards. The felling should ordinarily be completed by the middle of March in order that the felled refuse may have some time to dry properly. The best time to burn the area is a matter of considerable judgment. Ordinarily speaking the best time to burn is between the 10th and 15th April but it often happens in Burma, especially in Upper Burma, that there is a danger of hot weather showers interfering with the burning. In this case it is better to burn somewhat earlier rather than to risk delay by these early showers. A good fire is essential not only because it completely consumes all the cut refuse and so saves work afterwards but because a good fierce fire kills off the bamboo clumps, delays the growth of weeds and leaves the soil in a better condition for the crop. After burning it is usually necessary to heap and reburn the unburnt refuse, an operation known in Burmese as "*kyunkwe*." In the case of a badly burnt area this work is naturally heavy and, when the burning has been late, delays the sowing and weeding of the crop and may result in its partial or complete failure. Weeds usually appear as soon as the first monsoon rains have fallen. In Lower Burma these are generally expected at any time after the 15th May from which time rain usually falls frequently. In Upper Burma, though showers may be expected in May, the rains cannot really be relied on until much later and often fairly heavy rain in the latter half of May may be followed by a prolonged drought which renders regeneration extremely difficult. Even there, however, the May showers will invariably bring up the weeds. Before sowing the crop it is usually necessary for the *taungya* cutter to do a thorough clean weeding. These early weeds are known as the "*mibaung*" (fireweeds) and are of a somewhat different type to the later weeds known as "*sababaung*" (rice weeds). An important

part of the early weeding is the cutting back of all shoots springing up from bamboo clumps. This will be dealt with later under regeneration. After the weeding of the *mibaung*, which should usually be completed by the end of May or early June the crops are sown. The crops sown by the *taungya* cutters vary considerably. In the ordinary moist forest typical of the moist deciduous type in which the best teak grows, rice is always the main crop, while small patches of "*pyaungbu*" (maize), pumpkins of different kinds, beans, sessamum and cotton are grown, often mixed indiscriminately with the rice. In the drier types of soil, cotton, sessamum or even millet may form the major part of the crop; while on the Shan hills potatoes offer a very promising and paying crop. The earliest to be sown, as it is also the earliest to be reaped, is the maize. This is often put down at the very start of the rains, even before the early weeding is completed. It is usually dibbled at wide intervals in other crops and, if the main crop is rice, must on no account be sown at all densely. Beans, pumpkins and other vegetables are usually sown about the same time. The rice is not sown until all the early weeding has been completed. It is rarely if ever sown broadcast. Apart from the danger of all the seed sown in this way being washed down the slopes, rice seems always to grow better when three or four plants are clumped together. Moreover on good soil where the growth is vigorous the rice should be given plenty of room and must be spaced far wider than on poor soil. All experienced *taungya* cutters are fully acquainted with the best methods of sowing but often villagers are introduced who are not experienced and it is necessary for the Forest Officer to train them in the best method of sowing their crops. Rice is almost invariably dibbled. In most of Lower Burma the soil is notched by the men who use long bamboos with a small iron trowel (*tooywin*), at one end and by using the balance of the long bamboo they are able to make small shallow notches in the ground with the iron *tooywin* at intervals of about 9" to 1' or even more and cover the ground very rapidly. Other more primitive methods are to use just a short bamboo or wooden handle with the iron *tooywin* and make small notches but this is far less rapid than the expert use of the long bamboo. The women usually follow the men and place a few seeds of rice in each notch or pit. No attempt is made in the ordinary *taungya* to cultivate the soil in any way other than weeding and after sowing the paddy, the notches are left open. The sowing of the sessamum is usually done broadcast immediately before the soil is notched for the sowing of the rice. The object of this is to prevent the light seed from being washed away, as the notching, immediately after sowing, breaks the surface of the soil sufficiently to allow the seed to be caught up and so to germinate. Usually it is advisable when the

Plate II

Taungya cutters dibbling paddy.

sessamum is found to be growing up too thickly to thin out the plants both in the interests of the sessamum and of the rice. Provided the rains are propitious, the rice germinates within a day or two and when once it has started to grow a second weeding of the *sababaung* (rice weeds) is necessary, all bamboo shoots and coppice shoots being cut back as soon as they appear. Later a third weeding may be necessary but unless the weeds are very strong the rice is usually able to hold its own after the second weeding. The maize usually ripens about the latter half of July and has then to be reaped. From then until October, apart from occasional weeding where necessary, the *taungya* cutter has little to do. The rice usually starts flowering in October but the actual time varies considerably according to the kind of rice that has been sown. Once the grain has started to form the *taungya* cutter is kept fairly busy keeping wild animals and birds (especially parrots) from damaging the crops.

Rice is usually reaped in the latter half of November or the first half of December. Sessamum is usually gathered somewhat later, while cotton and vegetables continue producing well on into the following year.

Such is the ordinary routine of the work in a *taungya* in Lower Burma. Usually it is only possible to persuade the *taungya* cutter to take one crop off a *taungya* and the area is then abandoned though the *taungya* cutter may return the following year to collect *fruits* and vegetables and even cotton from his *taungya* of the previous year. In some cases in Upper Burma, where the soil is exceptionally rich, it is possible to take a second crop of early rice off the area by cutting over the straw and weeds and burning. This is also possible in some of the drier areas where owing to the poverty of the soil and the lack of material for the burning it is necessary to work the soil either by ploughing or hoeing. The cultivation of the area for a second year is of course a very great assistance when regeneration is combined with the *taungya* crop as it ensures a second year's weeding.

Before proceeding to detail how regeneration is fitted in with *taungya* it may be as well to note that it is essential for the welfare of the *taungya* cutters, (which is of course inseparable from the success of regeneration with *taungya*), that the agricultural problems in connection with the *taungyas* should be very carefully studied. Improved kinds of rice and other crops which will ensure a better return for the labour, better methods of treatment and the introduction of new and profitable crops should all be studied and experiments on the part of the *taungya* cutters should be encouraged by liberal supply of seed and even by assistance in the marketing of any surplus produce.

CHAPTER V.—ESTABLISHMENT OF TEAK REPRODUCTION IN *TAUNGYA*.

Having detailed the ordinary work carried out by the *taungya* cutter it is now proposed to show how the regeneration of tree species is combined with the *taungya*. To avoid confusion it will be as well primarily to deal only with the introduction of teak. noting later on the variations necessary for the introduction of a few of the other more important species. Before proceeding further it should be noted that our methods have mainly to be adapted to the production by the *taungya* cutter of a crop which will supply his own food during the year and from any surplus of which he can obtain the money to supply a few of his wants, such as clothes and extra food which he cannot himself provide. Moreover the work which he is asked to do must not in any case exceed the limit which he is prepared to give in return for the privilege of being given a rent-free area to cut for *taungya*, certain other privileges attached to the status of a forest villager and a small monetary reward in cash. Work in the production of a *taungya* crop is extremely arduous and employs to the full the *taungya* cutter for the greater part of the year. The methods by which the tree crop is introduced must therefore be as simple and as non-vexatious as possible.

1. Work in the first year.

(i) COLLECTION OF THE SEED.

Teak seed should be collected from sound vigorous trees at least 4′ in girth. It is best to select trees with wide spreading crowns situated in the open or on the edge of denser forest. The best time for collection varies in different parts of Burma. In Lower Burma collection may be started about the second half of February but in Upper Burma it should be carried out somewhat later. Early falling seed should be discarded. In the past the majority of seed in Lower Burma from which most of the indents for other parts of India have been supplied, have been collected from clumps of pure teak isolated in the middle of cultivation. These trees, probably on account of exposure to the sun and their wide spreadlnn crowns, usually produce abundance of seed which has been very easy to collect. Now that most of these teak clumps are being given up for permanent cultivation or other purposes, the collection of seed is more difficult, It is usually possible, however. to find suitable isolated trees from which all the seed required can be collected. Collection is

usually carried out by knocking the fruit off the trees with long bamboos either from the ground or by climbing into the trees. Teak usually seeds fairly freely every year, but though teak seed will keep fairly well for several years if carefully stored, it does not seem to germinate as readily after the first year, probably because the shell has hardened and is less pervious to moisture. It is however as well, in a good seep year, to collect a surplus in case the following year should fail to produce good seed.

The seed after being collected should be spread out to dry in the sun and after it is thoroughly dry can be packed in bags or heaped in a dry store room.

(ii) PREPARATION OF THE SEED BEFORE SOWING.

Much has been written on this in the past and the most satisfactory method of preparation has still to be discovered. As a matter of fact, in Lower Burma, wherever the rainfall is fairly heavy, early sowing usually gives fairly early germination and the use of any special measures are not of so much importance. In Upper Burma however the delayed germination of the seed almost invariably gives trouble. The difference is partly due to climatic conditions as in Upper Burma the early rains are uncertain and long spells of hot weather frequently come after the early showers. In Lower Burma where the rainfall is over 60 to 70 inches, the early rains are much more constant and the short spells of hot sun between the showers give probably ideal conditions for early germination. Apart from the difference in climatic conditions, however, it would seem that the teak seed of Upper Burma produces a thicker, tougher shell which also accounts for slower germination. Certainly teak seeds from Lower Burma when sown in Upper Burma seem to produce earlier and better germination.

With regard to the method of preparation, burying of the seed for a year certainly gave extremely good and early germination in the initial experiment, but subsequent experiment has shown that this success is not invariable. Both in Lower and Upper Burma, the writer has examined many samples of buried seed and while certainly the valves, which have to open before the seed can obtain the moisture to germinate, have usually been found to adhere but loosely to the seed after burying, the great majority of the seed has almost invariably been bad, having become damp. In the original experiment in Katha Division which was described in Burma Forest Bulletin No. 1, issued in 1921, great stress was laid on the importance of white-ants eating away the outer corky covering of the fruit and leaving the bare shell. Careful examination

of the seed in the course of germination on a seed bed has however shown that the absence of the corky covering so far from being an advantage is in all probability a serious drawback. The factors necessary for germination are moisture and heat combined. In the case of the bare shell, moisture has but little effect and as soon as a dry spell comes the shell dries up entirely. Where the corky covering is still present, this covering gets saturated with moisture during rain and when a dry spell comes does not rapidly lose the moisture, but on the other hand is in a better position to combine the two essentials of moisture and heat. It is not proposed to go into great detail as to the various methods of the preparation of seed for early germination. Reference is invited to Burma Forest Bulletin No. 1 and to Indian Forest Record, Vol. VIII, Part IV, pages 32 and 33. Suffice it to say that with the exception of burying the seed all the methods aim at the combination of the two essential factors for germination, heat and moisture. There remains, however, the method which on the whole has given the best results in Lower Burma and that is early sowing. It has been found that seed sown in Lower Burma without any special preparations, soon after the *taungya* fire and allowed to remain in the soil during the rest of the hot weather usually gives early and fairly thorough germination. No special preparation of the soil is necessary. Seed is usually sown on level patches at convenient spots throughout the area and seedlings are transplanted later.

(iii) SPACING.

In Burma in the past various spacings were tried such as $6' \times 6'$, $9' \times 4'$ and $12' \times 3'$. The main idea of these has always been to give the same number of plants to the acre, *i.e.*, 1,210. Latterly experiments of wider spacing such as $9' \times 9'$, $12' \times 12'$ and even wider have been tried but have not been a success. The main principle underlying the spacing must be the production of a canopy at as early a date as possible consistent with economy. With this in view a close spacing, provided the cost is kept down within reasonable limits, has been found to be best. A spacing of $6' \times 6'$ is now generally adopted but in view of the greater facility at weeding in following lines of plants closer than $6'$ apart experiments with such spacing as $6' \times 3'$ or $9' \times 3'$ are being made. An important point in connection with the spacing is the subsequent development of the crop and especially the thinnings that are necessary. In good teak localities it is found that teak plantations with a spacing of $6' \times 6'$ require thinning after 5 or 6 years A closer spacing in the lines will therefore necessitate an earlier thinning in order to prevent the saplings crowding each other. At the same time a thinning out of alter-

nate saplings in the line is a very simple operation whereas there is more chance of obtaining a full stocking in spite of some failures when the plants are only 3′ apart in the rows than when they are 6′ apart. The disadvantages of a wide spacing are that the plantation takes longer to form a canopy and therefore requires more expenditure on weeding while the failure to close up early tends to encourage forking of the leading shoot and vigorous growth of strong side branches.

(iv) STAKING.

Small split bamboo stakes from 18″ to 2′ 0″ long are put in to mark the spacing. While absolute accuracy is not essential, considerable care is required to see that the lines are kept reasonably straight and that the distances between pegs do not vary more than a few inches. The first step is to lay out guide lines and this should be done more accurately with a compass, care being taken to see that the guide lines cross at right angles. Intermediate staking can be done mainly with the assistance of rope knotted at suitable intervals and bamboo poles of the required length. Staking should be done only by reliable subordinates who require a certain amount of drilling. One important point is to see that staking is not done piecemeal but that the lines continue right through the whole area to be planted. This facilitates thinning, as, where staking is done separately for each *taungya* cutter's area, the junction between two areas often leads to complications in thinning when the lines are not continuous.

Staking must be carried out as early as possible as otherwise sowing of the teak seed is delayed. Care must be taken to see the stakes are driven firmly into the soil. Stakes are usually prepared by the *taungya* cutters and must be stout, as they are required to last through the rains.

(v) SOWING.

As a general rule sowing of the seed at stake is cheaper and more effective than planting from nurseries but in view of the importance of early sowing in the case of teak, and the delay often caused by having to wait until the staking is completed, early broadcast sowing of the teak on suitable level patches, from which transplants can later be moved to stakes, has proved to be the best method up-to-date. In adopting this method care should be taken to avoid sowing broadcast over large areas as owing to a number of seedlings being left *in situ* and not being required for transplanting considerable difficulty is caused subsequently in tending and thinning owing to the absence of definite lines. Small level places on good soil are selected at suitable intervals throughout the

area and the seed is sown broadcast on these, care being taken to see the seed is not sown too thickly as this makes transplanting with a ball of earth more difficult. This sowing should be done as soon after the *taungya* has been burnt as possible. Staking can then be done at the convenience of the *taungya* cutter and is not so urgent as would be the case when the seed is to be sown at stake. The teak seed should begin to germinate by the end of May and when germination has been well advanced the seedlings are lifted with a ball of earth and transferred to the stake. Seedlings may be transplanted soon after the first pair of real leaves is fully developed and an ordinary garden trowel has been found to be a very useful instrument for this purpose. Provided ordinary care is taken over transplanting and the work is only carried out in suitable weather either during rain or in the evening, the percentage of failures should be very low. One of the greatest advantages of this method is that only early germinating vigorous seedlings are transplanted to stake and this is of the first importance as the essential point in teak plantations is a complete stocking of vigorous seedlings in the first year. In the case of direct sowing at stake germination is very uneven and seedlings vary considerably in their vigour.

If seed is sown direct at stake 3 or 4 seeds should be used for each stake but care should be taken to see they are not sown close together. Either they may be sown in three or four separate pits round the stake or at intervals in a short trench. It would probably be beneficial to work the soil fairly thoroughly round the stake but so far this is not usually done. A small pit is made and the seed dropped into it, or the soil is slightly loosened and the seed pressed into the loose earth. On steep hillsides more care is necessary as seed is liable to get washed away with the loosened earth and in this case it has been found best to dig notches into the slope and avoid loosening the earth.

(vi) BROADCAST SOWING OF ACCESSORY SPECIES.

The object of this is to hasten the killing out of weeds and grass and to ensure a dense stocking as early as possible. The method was originally suggested by the success which attended the presence of natural regeneration of *hnaw* (*Adina cordifolia*), in a young teak plantation. It was found that the cost of weeding was considerably reduced by the dense stocking of *hnaw* seedlings which sprang up from seed shed by a seedbearer on the edge of the plantation. Later it was found that *binga* (*Stephegyne diversifolia*), also formed a dense stocking and while assisting greatly in suppressing the growth of weeds and grass grew somewhat slower than the teak and did not interfere with its growth. Broadcast

A teak plantation early in the second rains in which *hnaw* (*Adina cordifolia*) has been sown broadcast with a view to getting a dense stocking. Area has not yet been weeded.

A teak plantation 2 years old with dense undergrowth of *binga* (*Stephegyne diversifolia*) from broadcast and natural sowing. Illustrates good and rapid soil cover and absence of weeds.

A teak plantation with undergrowth of *pyinma* (*Lagerstroemia Flos-Reginae*) from broadcast sowing. Plantation 3 years old. Illustrates dense growth of *pyinma* and absence of weeds although teak stock is not particularly even.

sowing of these species was then tried and proved successful in many cases, more especially on level or slightly sloping ground, but was very uncertain on steeper slopes where the light seed was probably washed down by the rain. It was found that with a dense stocking of subsidiary species little if any weeding was necessary in the third year of the plantation, while the soil underneath the canopy was cleaned and kept cool and moist by the cover. There can be little doubt that this has made a great difference to the growth of the major species. The above two species are however light-demanders and, once the teak is well established, cease to have any useful function. *Pyinma* (*Lagerstroemia Flos-Reginae*) has also been tried and although it is not quite so good at covering the ground and killing out the weeds as the other two species it does give considerable assistance and moreover as it is a shade-bearer can continue under the canopy of the teak and form an undergrowth and possibly even a second storey of marketable timber. In view of the necessity for undergrowth in teak plantations the broadcast sowing of *pyinma* seems likely to give very valuable results. Other species have been tried with varying results. The essentials to success are :—

1. The accessory species must be slower growing than the major species unless the major species is a shade-bearer.
2. It must cover the ground rapidly.
3. The seed must be cheap and easy to sow broadcast.
4. Broadcast sowing must be done very systematically so that the whole of the area is covered.
5. Accessory species found interfering wit: the major species must be dealt with as weeds.

Were the results of broadcast sowing certain it would be justifiable to adopt a far wider spacing than 6′×6′. Probably a spacing with trees close together in the rows and wider intervals between the rows would be the best as weeding could be confined to the rows. A mistake has sometimes been made when weeding of assisting the accessory species as well as the major species. This makes the weeding much more expensive. Except possibly in the first weeding in the second year accessory species must be left to look after themselves, weeding being confined to the major species sown in lines.

(vii) PLANTING.

Owing to the uncertainty of germihation of teak seed, and the importance of ensuring vigorous seedlings in the first year, planting is being moie and more resorted to. The method of early sowing on selected patches in the plantation and subsequent transplanting has already

been dealt with. So far the use of regular nurseries with watering during the hot weather has not been adopted though, could the difficulty of finding a regular water supply close to the plantation area be got over, this would promise well. Usually only rough nurseries are made and the seedlings transplanted to stake with a ball of earth. Another method of planting is by the use of " stumps." So far this has not been generally used in the first year as the growth is so fast that it may interfere with the rice; the method is more adapted to filling up blanks in the beginning of the second year. At the same time the use of stumps is by no means as simple as some people seem to think. The writer has seen stumps being used that would require the greatest optimism to hope for success. Stumps should be carefully treated and cut cleanly. The side roots should be trimmed off with a sharp knife and not torn. Only a very short length of the stem should be left and it is found to be better to insist on ½" to 1" of stem only being left as there is then less danger of burying the stump too deep. The length of root to be cut depends on the size of the carrot-like portion of the tap root. On no account should the carrot be cut. The best size of stump is about the thickness of the forefinger, as the taproot is then 6" to 8" long. Larger seedlings produce larger stumps as the tap root is much longer. In planting out there are several ways. Wedge planting is probably the easiest and quickest, but subordinates usually dig a hole and plant the stump in the hole, pressing in the earth round the roots. Great care must be taken to see that the collar is on a level with the ground and is not buried too deep and that the soil is well pressed in round the roots. For ordinary planting by far the best method is to use small teak seedlings and transplant with a ball of earth leaving the roots undisturbed. The best size to use is when 1, 2 or 3 pairs of real leaves have been produced. Larger seedlings have longish roots and though transplanting is by no means difficult the operation requires more care and a larger ball of earth than most of the *taungya* cutters care to use. Planting should ordinarily be completed by the 15th June.

(viii) FILLING GAPS.

Early in July and before the rice gets too high the subordinate in charge should make a thorough inspection of the lines of seedlings and mark each blank with a six foot stake, so that it can easily be seen above the paddy. He should see that the *taungya* cutters fill up the blanks with transplants or " stumps " and the 6' stake should not be removed until a later inspection has shown that the blank has been successfully filled with a living plant.

(ix) WEEDING.

As already described the *taungya* cutter usually does one weeding, "*mibaung*," before sowing his rice and one later after sowing the paddy "*sababaung*." Unless he is properly supervised he will not trouble about bamboo clumps that have not been killed by the fire beyond cutting the shoots back. It is most important that all bamboos should be killed as otherwise expensive cleanings will be necessary for many years. A good fire is half the battle but clumps that have not been killed by the fire require constant attention. Every shoot should be carefully cut off close to the stump as soon as it forms and when these shoots arise between the bamboo stumps they are best cut with a small flat trowel fixed to the end of a bamboo handle. If this is done systematically early in the rains the bamboo clump can usually be killed.

Care must be taken to educate the *taungya* cutter to recognise seedlings of all trees useful as accessory species and avoid removing them when weeding.

(x) COUNTING.

The rice in the *taungyas* is reaped in the end of November or the beginning of December and as soon as the harvest is finished the *taungya* cutters have to clear the lines of all weeds and rice straw and replace all stakes that have been lost. At one time the practice of clearing the lines was given up as it was thought that the weeds and straw gave shelter to the young seedlings during the hot weather. This was a mistake. Teak seedlings that have been suppressed by the rice during the last 3 or 4 months of the rains can put on a very appreciable growth during the cold weather and such seedlings are in a very much better position to start a vigorous growth early in the following hot weather than seedlings that are kept in check by weeds and rice straw.

As soon as lines have been cleared and every space, where seedlings are or should be, has been staked, counting is carried out under the supervision of the Range Officer. This counting is done in various ways. The most usual way is for a pair of coolies to take a line. One man collects a stake from every space that has a living seedling while the second man notes on a thin strip of bamboo with nicks on it the number of blanks at the same time removing the stake left at all blanks and laying it alongside the place where the seedling should be.

(xi) PAYMENT.

The rates of payment vary very considerably, and depend mainly on the inducement necessary to encourage *taungya* cutters to work.

In some places *taungya* cutters do all the work free in return for permission to cut *taungyas*. This, however, is not usual and a small payment serves as an incentive to successful stocking. In some cases even the sowing, staking and planting may all be done departmentally, the *taungya* cutter only being responsible for seeing that the seedlings are properly weeded. The usual method is to give payments for the number of live plants found on the area, all the work, with the exception of the collection of the seed, being done by the *taungya* cutter. Rates vary from eight annas to Re. 1 per 100 established plants. A better method is to vary the rate paid according to the success attained. Thus a percentage of over 90% survival is paid for at Re. 1 per 100 ; 75% to 90% at 12 annas per 100 and 50% to 75% at 8 annas per 100. Under 50% success no payment is made. The full cost of an acre planted 6′ × 6′ with 1,210 plants is therefore just over Rs. 12 for complete success. A reduction in the rates may be made for areas where the *taungya* cutter has not killed the bamboo clumps or has left the are full of weeds.

The importance of a good stocking cannot be sufficiently emphasized. Not only does the weeding of a poorly stocked area cost very much more but even then the chances are against the plantation ever being well stocked—blanks are far more likely to extend than to close up, while thinning is very greatly complicated by the presence of large gaps in the canopy. Any extra payment for stocking over 90% is easily covered by saving in subsequent weedings, cleanings and thinnings.

Equally important is the vigorous and even growth of the seedlings. This is a matter that is very difficult to encourage by varying the rates of payment as it requires considerable judgment to decide whether the growth will pass the standard or not. Often teak seedlings after reaping the rice are weak with small leaves and are not in a condition to shoot ahead in the second rains. As a result weeding has to be continued for very much longer. On the other hand a crop of vigorous seedlings which has been enabled to produce large healthy leaves before the rice has suppressed it, can and does shoot up to a height of 6′ to 8′ in the second rains and is established rapidly and cheaply. The writer believes that the rotation necessary to reach a reasonable exploitable girth in the cases of two plantations on the same locality where in one case the seedlings at the end of the first year are strong and vigorous, while in the other case they are weak and small, may differ by as much as ten years. A plantation of small weakly seedlings takes years to establish itself and even then the growth does not compare with the growth in a plantation of vigorous seedlings which can establish itself in the second year,

(xii) SURVEY AND INSPECTION PATHS.

During the hot weather after counting, the area is mapped to show areas planted with different species. It is necessary to emphasise the importance of early survey. While the area is still clear of growth survey is a simple matter, long sights can be taken and the whole area can be mapped on a plane-table by intersection with the minimum of actual survey. Once the growth is up, however, survey must be a long and laborious business. A scale of 8″ to the mile is usually sufficient. Together with survey the laying out of a network of inspection paths is necessary. There are many who may scoff at the necessity of inspection paths but they do not realise what a dense growth springs up in these plantations in the first 3 or 4 years. Without paths it is impossible to inspect the area or to see that work such as weeding is being properly done, while paths also serve to split up the area into small blocks and ensure the more systematic working over of the whole area by weedings, cleanings and thinnings. Inspection paths should be laid out so that every part of the area can be seen. They should not follow the tops of ridges and spurs only but should be graded partly along the slopes. A maximum gradient of 1 in 6 is found to be suitable.

2. Work in the second year.

(i) BURNING AND FIRE PROTECTION.

Formerly teak plantations were usually burnt over before the second rains. It is still a disputed point as to whether this should be done or not. So far experiments show that results vary very greatly. In some cases burning undoubtedly keeps back the weeds and results in a vigorous growth of the teak. In other cases little if any advantage to the growth can be found, while strong vigorous seedlings undoubtedly receive a set-back. It is probable that in good plantations, in which the growth of the seedlings is vigorous and which have been well weeded, burning does more harm that good. In plantations which have not been kept clean of weeds or in which the seedlings are not very vigorous, burning undoubtedly does good as it retards the weed growth and gives the teak a chance of sending up vigorous shoots. Burning must therefore be considered as a possible palliative in plantations which have not succeeded as well as might be desired. It is not a regular part of the routine in a successful teak plantation. Should it be decided to burn the plantation it is often as well to cut back all vigorous seedlings, to avoid forking in the event of their not being burnt back to the roots. It may also be found necessary to cut back weeds to ensure a good fire. It is by no means always an easy matter to burn a plantation at this stage.

(ii) WEEDING.

It is important to do a very thorough weeding early in the second rains. Weeding is best carried out by following the lines and clearing back all weeds to a width of about 3′. Only higher weeds and creepers between the lines need be cut back. Often double shoots will be found owing either to burning or to more than one seedling springing up at each stake. All superfluous shoots or seedlings must be cut back. It is probable also that pruning of badly forked or damaged seedlings is beneficial. The weeding should be carried out by a gang of 8 to 10 coolies working along the lines under the supervision of a subordinate. Two coolies more skilled than the rest should follow with the subordinate in charge cutting back superfluous shoots, pruning and carrying out any weeding that has been omitted by the other coolies. In the case of a plantation that has not been very well stocked in the first rains patching all blanks is an important part of the work. This is best done with "stumps" and for this purpose it is as well to arrange for a nursery to be made each year to give one year old seedlings for "stumps" in the following year. All blanks should be staked and a hole dug in readiness for transplanting by stumps. This is best done by a separate party following the main weeding party. This weeding should be completed not later than the end of June. If there is much patching to do it should be completed before the end of May to give as good a start as possible. The second weeding must depend mainly on the vigour of growth, the amount and vigour of weeds and the amount of patching that has had to be done in the first weeding. In a good teak plantation where the stocking and vigour of the seedlings is good and where there is a good stocking of accessory species only a light second weeding about September should be necessary. The most important part of the work will consist in creeper cutting. In a plantation which has had to be patched or in which the seedlings are not very vigorous a second heavy weeding will be necessary in August and in very inferior plantations even a third weeding may be necessary. It cannot be sufficiently emphasized that a plantation that is successfully stocked with vigorous seedlings in the first year is by far the cheapest to establish. Extra expense on formation in ensuring success is always a sound investment as it will save subsequent cost of establishment.

3. Work in the third year.

(i) FIRE PROTECTION.

Even if the plantation has been burnt previous to the second rains, subsequent fire protection until the canopy is fully established and all

grass and weeds have been killed out is a *sine qua non.* The idea of replacing fire protection by early burning is believed to be wrong.

(ii) WEEDING.

In a good teak plantation in the third year little actual weeding is necessary. The canopy should already be forming, especially if there is a stocking of accessory species. All that should be done is a slight cleaning where necessary and—most important—a thorough climber cutting. In backward plantations a thorough weeding should be carried out but the best time to carry it out must depend on the vigour of the weeds, etc.

4. Subsequent Work.

(i) CLEANINGS AND THINNINGS.

This must depend mainly on the success of the plantation. A good plantation can probably be left alone in the fourth year though it still remains to be seen whether thinning at the end of the fourth year in a really good plantation on first quality locality should not be carried out. Although the canopy has by then fully closed up, it is believed that it is better to leave the plantation unthinned till the 5th year in order to allow the holes to clean themselves of their lower branches before carrying out the thinnings.

In a plantation that has not been so successful, cleanings must continue into the fourth year.

It is not proposed to deal with thinnings here. These are still in the experimental stage. The writer's views have recently been given in Burma Forest Bulletin No. 9.

(ii) FIRE PROTECTION.

Fire protection should be very carefully carried out during the early years in a plantation. Early and repeated burning has been tried, its chief advantages being economy and the avoidance of an accidental fire at the hottest time of the year. In theory it is sound but in practice it is found that as long as the canopy remains open and grass and weeds are still present in the plantation a fire causes considerable damage. Grass will burn sooner or later and when it burns will always cause a fierce fire, damaging or burning back saplings round it. This reduces the chances of the canopy closing up and encourages the grass eventually causing serious gaps, which are often extended by wind. Early and

repeated burning can undoubtedly be adopted as soon as the canopy has closed up completely and killed out all grass and weeds but even then it prevents the growth of an underwood which is essential to the well being of the plantation. The protection given to the soil in a teak plantation without undergrowth is very little, while the heavy drip of rain water from the large teak leaves is liable to cause denudation. An evergreen undergrowth is to be encouraged and for this purpose continued fire protection will probably be found advantageous.

A two-year old plantation of *pyinkado* (*Xylia dolabriformis*) planted 6′ × 6′. Slow growth compared with teak.

CHAPTER VI.—NOTES ON THE REPRODUCTION OF A FEW OF THE OTHER IMPORTANT SPECIES.

So far the regeneration of teak has been dealt with. The method of regenerating other species differs only in detail, the main lines being similar. It is proposed to note on a few species showing how the treatment differs with a view to illustrating how the characteristics of different species can be met.

1. Pyinkado (Xylia dolabriformis).

(i) SOWING.

Pyinkado is difficult to transplant and the seed is very expensive to collect so that sowing at stake must be adopted. The seed germinates extremely well, the chief danger arising from damage by insects, especially crickets, immediately after germination. *Pyinkado* seed germinates in about 5 days after rain so that very early sowing, as is the case with teak, is not necessary. Three seeds pressed into slightly loosened soil, each in a separate pit round the stake, is usually the best method but on steep slopes owing to the danger of loosened soil being washed out it is better to sow on small ledges cut out of the slope as in the case of teak.

(ii) SPACING.

Owing to the slower growth in the first two or three years and to the small leaves of *pyinkado*, which do not form a canopy so rapidly as teak, a somewhat closer spacing than 6′×6′ would be beneficial. At the same time the cost of seed and the cost of tending a large number of plants per acre in the first year prevents a very close spacing being adopted. A spacing of 3′ apart in the lines with lines varying from 6′ to 12′ apart is now being tried. Owing to the increased amount of weeding necessary in a *pyinkado* plantation it is probable that the closer spacing in the lines together with a wider spacing between lines which can be filled up by the broadcast sowing of accessory species is likely to lead to a fairly early establishment of the canopy.

(iii) BROADCAST SOWING OF ACCESSORY SPECIES.

Owing to the slow growth of *pyinkado* during the first two years the establishment of a dense crop of accessory species very greatly reduce

the cost of weeding. At the same time most of the more suitable accessory species usually sown with teak grow faster than *pyinkado* and great care must be taken to cut them well back near the *pyinkado* seedlings. The most suitable species so far are *hnaw* (*Adina cordifolia*), and *pyinma* (*Lagerstroemia Flos-Reginae*). *Pyinkado* appreciates side shade and can stand considerable shade when young but cannot develop strongly under cover. *Hnaw* is not altogether suitable as an accessory species as it grows too fast and must eventually be cut out in the interests of the *pyinkado*. *Pyinma* is likely to prove a suitable mixture of a more permanent character. *Binga* (*Stephegyne diversifolia*) has not proved to be satisfactory as it grows too rapidly. *Taukkyan* (*Terminalia tomentosa*) has been sown with *pyinkado* but, besides being a strong light demander, has such a similar rate of growth to *pyinkado* that it must enter into competition with it.

(iv) WORK IN THE SECOND YEAR AND AFTER.

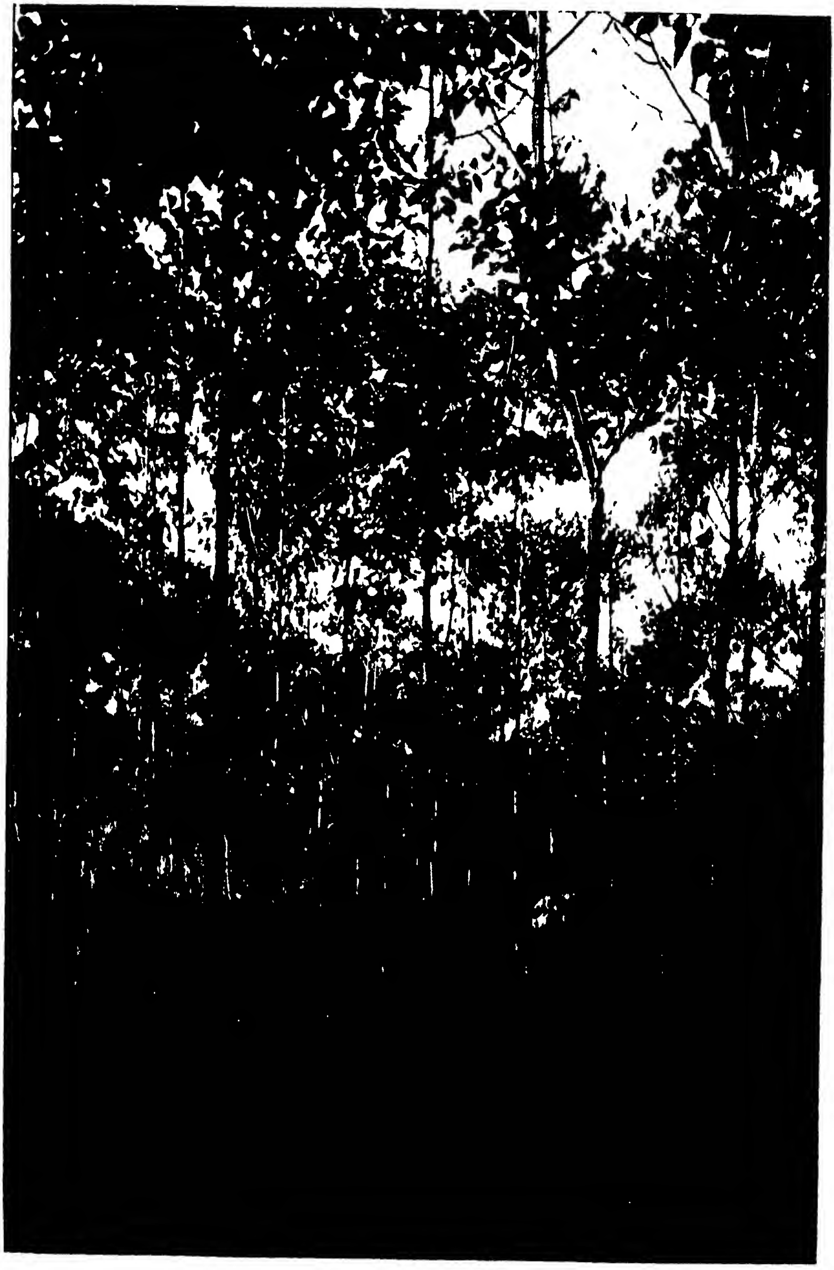
Strict fire protection is essential. Some *pyinkado* seedlings do survive a straw fire but a large percentage of seedlings are killed. Weeding is far more urgent in the case of *pyinkado* than teak and must be done as soon as the weeds start coming up. Owing to the leading shoots of *pyinkado* being very tender, climbers especially do much damage. Ordinarily the first weeding should be completed by the end of May. At least one and probably two more weedings are necessary later in the same rains.

Subsequent weeding and cleaning must depend on the vigour of the crop and of the weeds. Although *pyinkado* requires weeding longer than teak it can endure a certain amount of shade and is not so readily suppressed as teak. The weeding can therefore be confined mainly to the lines, thus reducing the cost. The principal damage is done by climbers. There is no experience as yet with regard to thinnings but *pyinkado* will certainly not require such early thinning as teak.

2. Taukkyan (Terminalia tomentosa).

The methods of regenerating *taukkyan* in *taungya* are very similar to those described above for teak. The seed in good years is plentiful and cheap to collect and good results have been obtained by broadcast sowing in addition to sowing at stake. The closer stocking seems to suit *taukkyan*. Seed germinates well and seeds from which the cotyledons are just emerging can be very simply transferred to stake. Weeding in the second year should be done early and *taukkyan* stands next to

Reproduction of *pyinma* (*Lagerstroemia Flos-Reginae*) from broadcast sowing in *taungya*. Two years old. An older teak plantation in background.



A four-year old plantation of *yemane* (*Gmelina arborea*). The plantation has just been thinned. Undergrowth of *pyinma* (*Lagerstroemia Flos-Reginae*) present but not very conspicuous.

pyinkado in the order in which weedings should be undertaken, "Stumps" can be used for patching in the second year in the same way as teak.

3. Pyinma (Lagerstroemia Flos-Reginae).

Except that the growth is rather slow there is little difficulty in regenerating *pyinma*. Seed is cheap and plentiful and germinates well and broadcast sowing is usually most successful. *Pyinma* stands considerable water logging and is a most useful species for regenerating on low lying land. Its close relation, the Andaman *pyinma* (*L. hypoleuca*), is even more promising and grows a good deal quicker, forming a dense canopy in 3 to 4 years when planted 6′×6′.

4. Yemane (Gmelina arborea).

Probably a very paying crop as its growth on suitable soil is so rapid that it establishes itself very early and is therefore very economical to tend. Moreover its rapid growth allows of its being worked on a short rotation which will probably not exceed 40 years. On this account it is not very suitable for growing in small blocks with other slower growing species. The methods to be adopted are similar to teak, save that it is usually found better to create nurseries and rely entirely on planting as germination is more regular in a nursery, and *yemane* is very easy to transplant. Seedlings up to a foot high are the best size but care should be taken to avoid handling the seedlings more than absolutely necessary and to transfer the seedlings as rapidly as possible. A spacing of 6′×6′ has usually been found suitable and with this spacing plantations should be established after the first weeding in the second rains. Thinnings should be carried out after the fourth year but great care should be taken to do them during the cold weather as otherwise much damage is done in felling owing to the stems being soft and easily bent over during the rains.

CHAPTER VII.—SPECIAL METHODS OF REGENERATION ADAPTED TO LOCAL *TAUNGYA* CUTTING CUSTOMS :

The methods outlined above are adaptable to the *taungya* cutting methods of the great majority of the population more especially on the Pegu Yomas. In some parts of the country, however, special types of cultivation exist and it may be interesting briefly to outline two or three cases where the methods of regeneration have been adapted to the local customs.

1. *Taungya* cultivation on the Shan plateau near Maymyo.

Recently attempts have been made to regenerate rapid growing species, and especially *Eucalypts*, for fuel and pit-props at Maymyo and near Namtu - the latter for the supply of mining timber to the Burma Corporation. The local method is to cultivate for two years running and ploughing is carried out in both years. The soil is not very rich and the original growth especially round Maymyo is not very dense while the exploitation of fuel has left insufficient material to give a good fire. The soil requires further preparation and this is done by collecting twigs, leaves and other refuse and mixing them with cow dung. This is set on fire and earth is piled over it. The earth is burnt brick red and after cooling, this burnt earth is scattered over the soil. The necessity of ploughing in the second year prevents the complete stocking in the first year but by spacing the stakes 9′ or 6′ apart in lines and leaving the lines 18′ apart half the area can be sown in the first year while still leaving room between the lines for ploughing in the second year. The intermediate line can then be planted up in the second rains. This may give a somewhat uneven growth which can usually be got over by sowing in the first year and planting one year old seedlings in the second year.

2. *Taungya* with a two years' cropping without cultivation of the soil.

This presents little difficulty provided the species to be planted will stand a light fire in the second year. The method is only possible on the richest soils. A crop of rice is taken off in the first year and the area is again burnt in the hot weather of the second year and a second crop is taken off the area. The reproduction is of course considerably assisted by the second season's free tending. In drier regions also a second year's crop of sessamum is in many places taken after a first crop of paddy. Sessamum is an even better crop than rice for the second year

as it does not interfere so much with the growth of the seedlings, and a second season's crop is well worth encouraging, especially with slow growing species such as *pyinkado*. The chief objection in this case is the necessity of burning the area during the hot weather of the second year.

3. Cultivation in the Dry Zone.

Considerable areas of reserve have been taken up in the Dry Zone, more especially in Meiktila Division for the conservation of the fuel and housepost supply to the local inhabitants. Mere protection has proved to be ineffectual in securing a good growth mainly owing to the condition of the soil, much of which had been cultivated in the past. All the better soils in these areas suitable for tree growth are also suitable for dry cultivation and are now being opened under a regular working plan combining the planting of tree seedlings at wide intervals with the cultivation of suitable crops by the villagers. The cultivation comprises a thorough ploughing of the soil followed by a crop such as sessamum, maize, millet or even tomatoes and vegetables. Cropping can continue on the same area for a number of years up to about 10 by which time it is thought that there should be a well established crop of tree saplings which should require little further tending. The principal species planted is cutch (*Acacia Catechu*), but *kokko* (*Albizzia Lebbek*) is also planted on the better localities and other species are being experimented with. So far it is too early to say if the method is likely to be successful but it promises well and fulfils the great aim of *taungya* regeneration, *i.e.*, the production of a forest crop combined with cultivation of suitable areas for food crops.

4. Regeneration with guava cultivation.

A most interesting adaption of the method of regeneration with *taungyas* is being tried in Insein Division on the Twante Kondan. The soil is poor and the existing forest growth has been so depleted by extraction that it is no longer capable of supplying the requirements of rightholders. Near by certain Shans have been in the custom of planting guavas for the Rangoon market. These men have been permitted to cultivate guavas inside the Reserve on condition that tree seedlings are planted at fairly wide spacing. A spacing of 15′×15′ has been adopted. Guavas come into bearing about the fourth year and are usually grown on an 8-year rotation so that by the time the guavas are finished the forest crop should be fully established. In the first year or two, vegetables also are planted, and the soil benefits considerably from the cultivation necessary.

5. Regeneration with sugarcane and vegetables on low lying land.

This method has given successful results in low lying land in the Plains Reserves in Tharrawaddy Division. Sugarcane is planted on banks raised above the level of the soil and the cultivation is extremely thorough. Seedlings of various species are planted out on these banks usually fairly late in the rains– September—after the worst floodirg is finished. The cultivation of sugar continues for two years, the cane being cut mostly during the cold weather. So far results are very good. Sometimes instead of sugarcane, vegetables such as bringals, tapioca, and sweet potatoes are cultivated on mounds, the tree seedlings also being sown or planted on the mounds with equally good results. The great trouble in these areas is the rapid invasion of the area by grass and, provided the level is not too low to cause bad water-logging, the thorough cultivation of the soil keeps out the grass very effectively.

6. Application of the method where *taungya* cutters cannot be obtained.

The principal advantage of the *taungya* is that it allows of very economical regeneration. There is however nothing against adopting precisely similar methods without *taungya* cultivation except foi cost and labour. Failing *taungya* cultivation the one aim must be the very early establishment of a canopy in order to reduce the cost of tending. The use of "stumps" or of large healthy nursery seedlings to ensure vigorous growth from the start coupled with a broadcast sowing of suitable accessory species will undoubtedly tend to earlier establishment. The principal extra costs over *taungya* cutting will be for the original cutting, burning and clearing, the sowing or planting of the seedlings and the weeding in the first year. Provided thorough weeding is carried out in the first year, the growth at the end of the year should be much more vigorous than in a *taungya* plantation where the seedlings are subject to suppression by the paddy.

Plate IX

A plantation of *pyinkado* (*Xylia dolabriformis*) on mounds with sugarcane on swampy ground.
Photo taken early in the third rains after planting.

ngya

A teak plantation, (6′ 6 and broadcast), after the close of the first rains. No paddy or other crop was taken off this area and photo shows the excellent growth of the teak which has been thoroughly weeded. Growth with paddy was not nearly so good.

CHAPTER VIII.—COSTS AND CONCLUSION.

Rátes vary considerably in different localities so it is extremely difficult to give any very accurate idea of the costs of a *taungya* plantation. The following may, however, be taken as a standard for maximum costs for a teak plantation in Tharrawaddy Division. The rate for coolie labour is now Re. 1 per diem and 90% survival and over is paid at Re. 1 per 100.

The following costs are given for complete success in the first year :—

	Rs. A. P. per acre.
First Year :	
Cost of seed, teak and accessory species	2 0 0
Reward to *taungya* cutters 1,210 plants @ Re. 1 per 100	12 0 0
Remission of capitation tax to *taungya* cutter	1 4 0
Survey	0 8 0
Inspection paths	2 0 0
TOTAL COST IN FIRST YEAR	17 12 0
Second Year :	
1st Weeding	3 0 0
2nd Weeding and creeper cutting	1 8 0
TOTAL COST TO END OF SECOND YEAR	22 4 0
Third Year :	
Weeding	2 0 0
TOTAL COST TO END OF THIRD YEAR	24 4 0

The plantation should then be fully established. It will probably require a light cleaning and creeper cutting in the 4th year at a cost of Rs. 2 per acre and a thinning in the 5th or 6th year at a cost of Rs. 3 per acre bringing up the total cost to Rs. 29-4-0 or say roughly Rs. 30 per acre. This cost would be considerably reduced in localities where the price of labour is lower. The total cost amounts to 30 coolie-days per acre. At 8 annas per diem the cost would be Rs. 15 per acre while at 12 annas per diem the cost would be Rs. 22-8-0 per acre.

In the case of a less successful plantation with say 80% survival the cost would be as follows .—

	Rs. A. P. per acre.
First Year:	
Reward to *taungya* cutters 968 plants @ 12 annas per 100	7 4 0
Other expenses as before	5 12 0
TOTAL	13 0 0

	Rs.	A.	P.
Second Year :			
1st Weeding including patching	4	0	0
2nd Weeding including patching	2	0	0
TOTAL TO END OF SECOND YEAR . .	19	0	0
Third Year :			
1st Weeding	3	0	0
2nd Weeding	1	8	0
TOTAL TO END OF THIRD YEAR . .	23	8	0
Fourth Year :			
Weeding	3	0	0
Fifth Year			
Cleaning			
Sixth Year			
Thinning			
	31	8	0

The cost would therefore be greater while the results would not be so good as an area that was fully stocked in the first year.

For slower growing species such as *pyinkado* or *taukkyan*, there would probably be a third weeding at a cost of Re. 1-8-0 in the second year and second weeding at the cost of Rs. 2-0-0 in the third year but otherwise the cost should be similar to that in the successful teak plantation and the cost at the end of the sixth year would be Rs. 32-12-0 or say Rs. 33 per acre. The above costs should be taken to be the maxima and may often be considerably reduced.

In the case of regeneration where *taungya* cutters are not available and all cutting, burning, planting and weeding has to be done departmentally the cost may be roughly estimated as follows :—

	Rs. per acre.	A.	P.
Cutting, burning and clearing	15	0	0
Planting, including cost of nursery and seeds	8	0	0
Weeding in the first year, three times	6	0	0
Weeding in the second year, twice	4	0	0
TOTAL TO END OF 2ND YEAR . .	33	0	0

Subsequent costs would be the same as in an ordinary *taungya* plantation, *i.e.*, Rs. 7 bringing up the total cost to Rs. 40.

CONCLUSION.

The greatest advantage of the adoption of *taungya* cultivation for regeneration is that it combines the production of a food crop with the forest crop and renders possible at a comparatively low cost the establishment of the labour force necessary. It thus solves one of the most difficult problems in connection with forest work on a large and intensive scale. It can, however, only prove successful if the *taungya* cutter receives all consideration and if the method of introducing the forest crop is adapted to the local customs or crops. The writer has tried to outline the typical case of regeneration with *taungyas* and has also given some instances where regeneration has been adapted to local customs. It remains for forest officers, who are able to employ local cultivators, to adapt their methods similarly.

APPENDIX.

A typical programme of work to be carried out in the regeneration of a forest with taungya.

NOTE.—The year should be taken as the Forest year, *i.e.*, 1st April to 31st March.

Seventh year before regeneration.—(Only when girdling before extraction is necessary.)

Stock-mapping of the coupe and compilation of the regeneration plan. (Chapter III, sections 1 to 3.)

Girdling of teak (and other species when necessary).

Sixth year before regeneration. *Fifth year before regeneration.* *Fourth year before regeneration.* *Third year before regeneration.*	} *nil.*

Extraction of girdled teak. In the case of areas where there is no necessity to girdle before extraction, the stock-mapping and compilation of the regeneration plan would be carried out before extraction in the fourth or third year before regeneration.

Second year before regeneration.—Extraction of other species.

The year before regeneration—31st October.—Preparation of final regeneration plan, based on the original stock-map and regeneration plan and showing areas to be planted with the different species, to be completed. (Chapter III, 6.)

31st December.— Allotment of areas to *taungya* cutters to be completed. (Chapter III, 6.)

15th January.—Cutting of *taungyas* to commence. (Chapter IV.)

15th March.--Cutting of *taungyas* to be completed. (Chapter IV.)

First year of regeneration—March and April.—Collection of seed to be completed. Amount required should have been based on the regeneration plan. [Chapter V, 1 (i).]

Early April.—Burning *taungyas* to be completed not later than 20th April. (Chapter IV.)

5th May.—Heaping and reburning of unburnt refuse to be completed. (Chapter IV.)

31st May.—Staking and sowing of tree seeds at stake and broadcasting of accessory species to be completed. (In the case of teak, sowing should if possible be completed on suitable plots throughout the area by 30th April.) [Chapter V, 1 (iv) to (vii).]

Middle of May to 15th June.—Sowing of field crops. (Chapter IV.

July.—Inspection of lines by subordinate and staking and planting up of blanks. [Chapter V, 1 (viii).]

July to November.—Tending of tree seedlings in conjunction with the field crops. [Chapter V, 1 (ix).]

November and December.—Reaping of field crops. (Chapter IV.)

January.—Clearing of lines, restaking and counting of seedlings surviving and payment of *taungya* cutters. Survey to be carried out and inspection paths made. [Chapter V, 1 (x) to (xii).]

March.—Fire protection of regeneration. [Chapter V, 2 (i).]

The second year.—April and May.—Fire protection to be continued up to the break of the rains. [Chapter V, 2 (i).]

May.—First weeding and filling of gaps to be completed by the end of May or 15th June at latest. [Chapter V, 2 (ii).]

September.—Second weeding. [Chapter V, 2 (ii).]

March.—Fire protection. [Chapter V, 3 (i).]

The third year.—April and May.—Fire protection until the break of the rains. [Chapter V, 3 (i).]

June.—First weeding. [Chapter V, 3 (ii).]

September.—Second weeding if necessary. [Chapter V, 3 (ii).]

March.—Fire protection. [Chapter V, 4 (ii).]

The fourth year,—April and May.—Fire protection until the break of the rains. [Chapter V, 4 (ii).]

June and July.—Cleaning if necessary. [Chapter V, 4 (i).]

March.—Fire protection. [Chapter V, 4 (ii).]

The fifth year—April and May.—Fire protection. [Chapter V, 4 (ii).]

November—December.—Cleaning, creeper cutting and thinning. [Chapter V, 4 (i).]

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(PARTS I, II and III as on Title page.)

INTRODUCTION.

The new genera and species of Brenthidae described by Herr Kleine of the Board of Agriculture for the Province of Pomerania, Germany, are based on the material in the collections of the Forest Research Institute, Dehra Dun, the Indian Museum, Calcutta, and the British Museum, London. Our information regarding the occurrence of species of this family in India was until quite recently very meagre. When catalogued by Von Schönfeldt in the Genera Insectorum, and the Coleopterorum Catalogus in 1908, fifty-four species were known from British India, of which only ten had been found in India exclusive of Burma and Ceylon. The bionomics of the family were almost entirely unknown. Stebbing in 1914 was able to give biological notes on only five Indian species, suggesting that some were predaceous in the larval stage, and others were probably true wood- and bark borers. At the present time about 240 species of Brenthidae have been collected in the Indian region, and an insight has been obtained into the breeding-habits and food-plants of several species.

An account of the importance of the Brenthidae to forest trees in India is given in part 2 of the present Record. Descriptions of the early stages in two genera form the subject of part 3.

The systematics of the oriental Brenthidae have been entirely neglected for the last thirty-five years by British entomologists; we are indebted to two Italian investigators, Senna and Calabresi, and to the modern world-specialist Kleine for the progress that has been made in classification.

C. F. C. BEESON,

Forest Entomologist, Forest Research Institute.

February, 1924.

PART I.

Neue Brenthiden aus Britisch Indien und den anliegenden Gebieten.

VON

RICHARD KLEINE, Stettin, Germany.

Herr Dr. C. F. C. Beeson, Dehra Dun, veranlasste mich, das im Besitz des Forest Institutes befindliche Material zu bearbeiten. Gleichzeitig bat mich Herr Dr. Beeson, die Brenthiden im Catal. of Ind. Ins. zu verfassen und ich bin auch diesem Ersuchen gern nachgekommen. Um nun den Catalog so vollständig wie möglich zu machen, habe ich zuvor das gesamte Brenthiden material des Britischen Museums und des Indian Museums durchgesehen, bestimmt und die neuen Formen festgelegt. Die neuen Gattungen und Arten sind nachstehend mitgeteilt.

CALODROMINI.

Cyphagogus concavus n. sp.

Rotbraun bis schwarzbraun, glänzend.— Kopf gedrungen, fast 4-eckig, auf Scheitel und Stirn nur sehr zart und zerstreut punktiert, an den Seiten und am Hinterkopf mit einzelnen groben, behaarten Punkten. Rüssel klobig, wenig schmaler als der Kopf, flach aber deutlich gefurcht. Vorderrand in der Mitte mässig eingebuchtet, Punktierung kräftiger als auf dem Kopf. - Fühler gedrungen, 2. Glied kaum länger als das 3., kegelig, 3. von ähnlicher Gestalt, gedrungen, 4.-8. quer, erheblich breiter als lang, 9. und 10. bedeutend vergrössert, breiter als lang, subquadratisch, 11. stumpflich-konisch. Alle Glieder locker stehend, vom 9. ab plattgedrückt, Unterbehaarung nur auf dem 11. Gliede. Thoracalconus sehr breit und wenig entwickelt, Furche breit und flach. Skulptur allgemein sehr zart und einzeln, in den Punkten zart, mittellang behaart,— Elytren nur mit 7 Rippen. Diese sind flach, kantig, so breit wie die Furchen und zerstreut, grob punktiert, in den Punkten behaart, Furchen ungegittert.— Vorderschienen mit kleinem aber deutlichem Haarbüschel, Hinterschenkel zart, Keule wenig gegen den Stiel abgesetzt, am Übergang zur Keule nicht verengt oder eingekerbt, Metatarsus so lang wie das 2. und 3. Glied zusammen,

kegelig, Klauenglied kräftig aber nicht walzig. Die grossen Vorderschenkel sind auf der Oberseite, etwa in der Mitte mit einer grossen, über das ganze Organ reichenden trichterartigen Grube versehen.— Metasternum zerstreut, grob punktiert, schmal gefurcht, Abdomen ohne Punktiertung, ungefurcht.

Länge (total): 8·0 mm. *Breite* (Prothorax): 1·0 mm. circa.

Heimat: Penang. Aus Sammlung G. Bryant.

Typus im British Museum.

Die neue Art kann vieleicht auch schwarz von Farbe sein, auf die braune Ausfärbung ist kein allzuhoher Wert zu legen. Grundsätzliche Trennung von allen bekannten Arten ist der flache Thoracalconus, die oberseits grubigen Vorderschenkel und die queren, walzigen Fühlerglieder. Beachtenswert sind die scharfkantigen Rippen und das Fehlen jeder Gitterfurchung. Die Stellung dürfte bei *delicatus* Lea sein.

Cyphagogus confertulus n. sp.

Hellschokoladenbraun, Halsrand, Rüssel an den Seiten, Vorderkante der Fühlerglieder und Schenkel. Schienen und Tarsen an Basis und Spitze schwarz, Elytren ohne Makel, oberseits mässig, unterseits stark glänzend. – Kopf erheblich länger als breit, parallel, schwach gewölbt, ungefurcht, einzeln kräftig punktiert und in den Punkten zuweilen lang behaart. Seiten und Unterseite sehr zart und einzeln punktiert, über den Augen eine einzelne, langbehaarte Punktreihe. Rüssel viel länger als der Kopf, das Metarostrum von Kopflänge, in den basalen 2/3 noch wie der Kopf skulptiert und matt, nach vorn glänzend und sehr fein punktiert, Meso und Prorostrum desgl. – 1. Fühlerglied krugförmig, 2. ohne Stiel, etwa quadratisch, 3, kurz, kegelig. 4.– 5. kaum breiter als lang, fast quadratisch. 6.– 8. viel breiter als lang, nach aussen spitz werdend, 9. und 10. von ähnlicher Gestalt, aber bedeutend länger, doch immer noch breiter als lang, 11. platt, stumpfkonisch, so lang wie das 9 und 10. zusammen, 1.– 5. eng stehend, die folgenden locker, die dichte Skulptur auf dem 9. und 11. Glied nur seitlich. Prothorax hinten stark verengt, Conus breit, flach, breitgefurcht, Skulptur grob, Behaarung lang.— 2 Rippe der Elytren sehr schmal, nur an Basis und Absturz breiter, alle anderen Rippen scharf konvex, Furchen überall kräftig gegittert.— Vorderschienen mit starkem Haarbüschel, Hinterschenkel am übergang zur Keule oberseits eingebuchtet, unterseits fast gerade, Metatarsus der Hinterbeine kegelig walzig, wenigstens so lang wie das 2. und 3. Glied zusammen.— Metasternum und Abdomen an den Seiten grob punktiert, sonst fast glatt, 3.— 5. dicht punktiert. Metasternum kurz gefurcht, 1. Abdominalsegment an der Basis mit undeutlicher, kurzer Furche.

Länge (total) : 9·5.—11·0 mm. *Breite* (Prothorax) 1·5—1·75 mm.

Heimat : Burma, Ruby Mines, 2. Stück aus Coll. Fry, von Doherty gesammelt. U. Dihing, Lakhimpur, Assam, 27, V. 1921 von Dr. C. F. C. Beeson gesammelt.

Zahlreiche Stücke im Indian Museum : Andaman Isl.

Eine Verwechselung mit irgendeiner anderen Art ist ausgeschlossen. Die rothbraune Farbe in Verbindung mit dem über den Augen punktiert gefurchten und behaarten Kopf ist bei keiner andern Art beobachtet worden. Die eigenartige Anordnung der Fühlerglieder habe ich bei keiner andern Art gesehen.

Cyphagogus confidens n. sp.

Dem *Sarasini* Senna nahe stehend und durch folgende Merkmale leicht zu trennen. Die Fühler sind von anderer Gestalt. 1. Glied länglich-krugförmig, 2 kegelig, kürzer als das 3. 3.- 6. kegelig, etwa gleich lang, nach vorn zu platter werdend, 7. zwar noch von kegeliger Gestalt, aber fast quadratisch, 8. breiter als lang, vordere Kante schief, 9.- 11. erheblich vergrössert, 9. länger als breit, vorn abgeschrägt, 10. etwa quadratisch, ebenfalls abgeschrägt, 11. stumpfkonisch. Vorderschienen mit kräftigem Haarbüschel. Bei *Sarasini* fehlt dieser Haarbüschel oder er ist klein. Auf jeden Fall sind die Fühlerglieder platt, linsenförmig und nicht lang kegelig.

Länge (total) : 10·0 mm. *Breite* (Prothorax) : $1\frac{1}{3}$ mm.

Heimat : Siam.

Typus dieser und der vorigen Art im British Museum.

Cyphagogus fragosus n. sp.

Dunkel schokoladenbraun, Vorder und Seitenrand des Rüssels, Kanten der Fühlerglieder, Halsring, Kanten des Conus, der Schenkel, Schienen und Tarsen schwarz, Glanz mässig.- Kopf schlank, konisch, nach den Augen erweitert, Hinterrand so breit wie der Hals, Oberseite gewölbt, dicht chagriniert und einzeln kräftig punktiert, über den Augen eine grobe, langbehaarte Punktreihe.- Metarostrum nach dem Mesorostrum verschmälert, länger als das Prorostrum, mit einer kurzen, schmalen Mittelfurche, in den basalen 2/3 wie der Kopf chagriniert, nach dem Mesorostrum glatt, glänzend, Punktierung im chagrinierten Teil wie auf dem Kopf, in der glatten Zone zart, einzeln ; Mesorostrum wenig erweitert, Prorostrum nach dem Vorderrande keilförmig erweitert, überall einzeln, zart punktiert, glatt.– Fühler gedrungen, robust, 1. Glied walzig, 2. quadratisch, 3. etwas länger als breit 4. quadratisch,

5.—8. breiter als lang, 9. und 10. quadratisch, 11. stumpf-konisch, Behaarung sehr schwach. Conus des Prothorax schräg, breit, seitlich mit scharfen Kanten, am Hinterrande seitlich stark eingedrückt, Punktierung auf der Oberseite im basalen Teil sehr grob, tief, einzeln, nach dem Conus wird die Punktierung flacher, kleiner und dichter, Seiten etwas weniger dicht punktiert; Oberseite matt, Seiten glänzend, Behaarung einzeln, lang.— Elytren sehr grob, tief und entferntstehend gegittert, Sutura erhaben, dachförmig, 2. Rippe an der Basis breit und flach, sonst schmal und tiefliegend, 3. und 4. an der Basis von gleicher Gestalt, im übrigen kräftiger als die 2., die folgenden schmal, die 2. 4. in der flachen Zone durch schräge Kiele verbunden, Behaarung einzeln. Hinterschenkel über die Elytren hinausragend, Stiel vor der Keule ober- und unterseits verengt, Behaarung einzeln, Schienen normal. Metatarsus kegelig, so lang wie das 2. und 3. Glied zusammen, Klauenglied kegelig, seitlich etwas zusammengepresst. Metasternum schmal gefurcht, Abdomen ungefurcht, einzeln, zart punktiert.

Länge (total): 11·5 11·0 mm. *Breite* (Prothorax): 1·5 2·0 mm.

Heimat: Above Tura, Garo Hills, Assam 3,500 3,900 ft. 15 VII 30. VIII. 17. Sammler: Kemp.

2 Exemplare im Indian Museum.

Die Art ist mit *confertulus* verwandt, von der sie sich durch den stark chagrinierten Kopf und das im basalen Teil gleich beschaffene Metarostrum, ferner durch den breiten Thoracal conus, dierobuste Punktierung desselben und durch die bisher ganz unbekannte Art der Rippenbildung auf den Elytren leicht unterscheidet. *Confertulus* ist eine kleine, schlanke Art, *fragogus* der grösste *Cyphagogus* den ich bisher gesehen habe.

Allaeometrus deformis n. sp.

♂ Ausfärbung gleich *breviceps* Senna. Kopf erheblich breiter als lang, Hinterrand kurz, dreieckig, in der Mitte eingekerbt, Punktierung kräftig, einzeln, an den Augen behaart, Unterseite lang, bärtig behaart. Metarostrum schmaler als der Kopf, Unterseite am Rande eckig erweitert, Mesorostrum stark erweitert, Metarostrum flach aber deutlich gefurcht, auf dem Mesorostrum erweitert, Punktierung dicht und tief.— 1. Fühlerglied mässig gross, 2. und 3. kegelig, gleich lang, 4.—8. viel breiter als lang, scharfkantig, 9. und 10. wenig breiter, quadratisch, 11. lang konisch, so lang wie das 9. und 10. zusammen, alle Glieder locker gestellt, tief grubig skulptiert, kräftig behaart.- Prothorax am Halse breit, gedrungen, vor dem Halse breit eingedrückt, die Seitenränder flach.—Auf den Elytren ist die 2. Rippe nicht so deutlich entwickelt als bei *breviceps*. Sonst alles wie dort. -

Metasternum und Abdomen breit und deutlich gefurcht und abstehend behaart.

♀ Mittlere Fühlerglieder kegelig, Kopf unterseits ohne Verdickung auf den Rändern, nur kurz und einzeln behaart, Metasternum und Abdomen kaum grubig, flach eingedrückt.

Länge (total) : ♂ ♀ 5 7 mm. *Breite* (Prothorax) : 1—1·25 mm.

Heimat : Assam, Kachugaon, Goalpara, 15. IV. 1906. Von E. P. Stebbing gesammelt.

Typus im Besitz des Forest Research Institute, Dehra Dun. [This species is recorded by Stebbing in Forest Bulletin No. 11, 1907, pp. 43, 44 and figured on Plate VI, f. 11, 11*a* under the name of *Brenthus* sp. (235 1906). The information is reproduced in Indian Forest Insects, 1911, pp. 391, 392 under the name of *Zemioses* sp. C. F. C. B.]

Opisthenoxys famulus, n. sp.

Rötlich kastanienbraun.— Kopf breiter als lang, Hinterrand gerade, scharf vom Halse abgesetzt, Oberseite gewölbt, ungefurcht spiegelglatt, einzeln, zerstreut punktiert, in den Punkten einzeln, lang behaart; Unterseite ohne Zahn, gerade, mit zarten, kammborstigen Haaren besetzt; Augen klein, dicht am Rüssel stehend.— Rüssel schmaler als der Kopf, grubig vertieft, Metarostrum erweitert, eine dreieckige, Vertiefung bildend, der Rand der Vertiefung ist dicht punktiert, die Vertiefung setzt sich auf das Prorostrum fort, dieses gegen den Vordrrand stark verbreitert. - 2.- 8. Fühlerglied etwas länger als breit, walzig, 9. 11. Glied vergrössert, plattgedrückt.-- Prothorax im basalen Teil tief punktiert, in den Punkten, namentlich an den Seiten, lang und zart behaart, am Halse etwas verengt, oberhalb durch einen Quereindruck abgeschlossen.- Elytren ähnlich = *breviceps*, 2. Rippe kurz, 3. nur mässig erhöht, breiter als alle anderen Rippen und mit einer breiten Punktreihe, Seitenfurchen gegittert, auf den Rippen einzeln, kurz behaart. Beine einzeln lang behaart. - Pro-,Metasternum und Abdomen einzeln punktiert und lang, zart behaart.

Länge (total) : 6·0 mm. *Breite* (Prothorax) : 1·0 mm. circa.

Heimat : Pashok, 2,000 ft., Darjeeling, E. Himalayas, 26. V.—14. VI 16. Sammler : F. H. Gravely.—

Typus im Indian Museum.

Die neue Art passt am besten zu *Opisthenoxys*, nur die verkürzte 2. Rippe stört und erinnert an *Allacometrus*, aber die ganze sonstige Rippenbildung, namentlich die breite 3. Rippe spricht für die angenommene Gattung. Von den übrigen *Opisthenoxys*—Arten trennt die tiefe Thoraxfurche und die überall vorhandene, lange Behaarung.

PARUSAMBIUS n. g.

Kopf breiter als lang, robust, scharf vom Halse getrennt, Hinterrand gerade Scheitel undeutlich gefurcht, Stirn ungefurcht, Unterseite ohne Zahn, Augen gross, fast den ganzen seitlichen Kopf einnehmend, nach vorn stehend.— Metarostrum schmaler als der Kopf, tief und schmal gefurcht, Mesorostrum nur wenig verbreitert, ebenso gefurcht, Prorostrum gegen den Vorderrand stark erweitert, gerade. Basis gefurcht, sonst glatt, Mandibeln gross, robust, untereinander geschlagen. Fühler in Rüsselbreite stehend, kurz, gedrungen, 1. Glied kurz, dick, 2.- 8. breiter als lang, nach vorn zu breiter und kürzer werdend, 9.- 11. erheblich vergrössert, 9. länger als das 10., 11. lang elliptisch, länger als das 9. und 10. zusammen, alle Glieder locker stehend, 9.- 11. seitlich plattgedrückt, die anderen rund.- - Prothorax eiförmig, in der basalen Hälfte schmal aber deutlich gefurcht.- Elytren an der Basis gerade, gegen den Absturz allmählich verengt und spitz gerundet, 2., 4. und 6. Rippe etwas schmaler als die anderen, an der Basis verschmelzen die Rippen der Oberseite zu einer runzeligen Partie; Rippen einzeln punktiert und behaart, Furchen undeutlich gegittert. Hinterschenkel nicht bis zur Elytrenspitze reichend, Stiel breit, schmal, Keule klobig, seitlich zusammengedrückt, Schienen robust, nach den Tarsen zu keilförmig vergrössert, Tarsen mittelstark, Metatarsus so lang wie das 2. und 3. Glied zusammen, Klauenglied zart, keulig, Vorder und Mittelbeine mit kurzen, breiten Schenkeln, Schienen und Tarsen ohne besondere Eigenschaften.- Metasternum schmal gefurcht, Abdomen ungefurcht, Quernaht nur an den Seiten deutlich.

Typus der Gattung: *P. fraudulentus* n. sp.

Ich kenne keine Gattung der orientalischen Region in der das Tier zu bringen wäre. Die hypermorphen Hinterschienen verweisen es in eine Verwandtschaft, die ich im Orient überhaupt noch nicht gesehen habe und die ausser der *Cyphagogus* - Verwandtschaft eigentlich nur in der äthiopischen Region stärker ist. Die meiste Ähnlichkeit besteht auch mit der Gattung *Metusambius* Kolbe, von der sie sich durch die Art der Rippenbildung auf den Elytren und durch den schmalen Prothorax leicht trennen lässt.

Parusambius fraudulentus n. sp.

Dunkelkastanienbraun, am ganzen Körper hochglänzend. Kopf und Rüssel einzeln aber kräftig punktiert, Unterseite mit borstiger Behaarung.— 1.— 8. Fühlerglied einzeln beborstet, 9.- 11. an den Seiten mit kurzer, dichter Behaarung.— Prothorax einzeln aber recht deutlich punktiert.— Hüften, Metarostrum und Abdomen einzeln aber kräftig punktiert, Beine mit grober Skulptur.

Länge (total) : 11·0 mm. *Breite* (Prothorax) : 1·5 mm.
Heimat : Above Tura, Garo Hills, Assam, 3,500—3.900 ft., 15. VII.—30. VIII. 17. Sammler : Kemp.
Typus im Indian Museum.

STEREODERMINI.

Cerobates collectivus n. sp.

Kastanienbraun, glänzend. Kopf am Hinterrande schwach eingekerbt oberseits sehr zart gefurcht, einzeln punktiert, seitlich unter den Augen mit einer Rinne, die am Hinterrande grubig vertieft ist; Augen sehr gross, fast den Hinterrand erreichend. Metarostrum so lang wie das Prorostrum, mit breiter, auf der Stirn beginnender Mittelfurche, Mesorostrum schmaler, Prorostrum nur an der Basis gefurcht.— 2.— 10. Fühlerglied etwa gleich lang, 11. fast so lang wie das 9. und 10. zusammen, alle Glieder zart, weiss behaart.-- Prothorax schlank, durchgehend tief gefurcht, am Halse stark zusammengeschnürt, einzeln punktiert.— Elytren durchgehend 3-furchig, Seitenrippen flach aber deutlich vorhanden, kräftig punktiert. Beine normal.- Metasternum, 1. und 2. Abdominalsegment schmal und tief gefurcht, 5. Segment glatt, nicht grubig vertieft.

Länge (total) : 7 mm. *Breite* (Prothorax) : 1 mm. circa.
Heimat : Burma Ruby Mines. 5,500 - 5,700 ft.
Typen im British Museum.

Diese Formen der *Cerobates* Arten haben im indischen Gebiet bisher keinen Vertreter. Als nächste Art wäre *C. aduncus* Kln. zu nennen, die aber wie die in den Verwandtschaftskreis gehörende *C. Sennæ* Calabr. zum aethiopischen Gebiet gehört. Von *aduncus* trennen die grossen Augen, die in allen Gliedern gleich grossen Fühler, das lange Spitzenglied, (bei *aduncus* ist das 11. nur so lang als das 10.), der durchgehend gefurchte Prothorax, das nicht grubig vertiefte 5. Abdominalsegment.

Cerobates concisus n. sp.

Einfarbig kastanienbraun, glänzend.- - Kopf am Hinterrand dreieckig eingekerbt und auf den Hals züruckgezogen, ungefurcht, zwischen den Augen mit beginnender Mittelfurche, Augen in halbem Durchmesser vom Hinterrand des Kopfes entfernt.—Metarostrum tief gefurcht, Meso-und Prorostrum ungefurcht.—Fühler : 1. Glied gross, 2. kurz, das kürzeste von allen, 3.-- 10. fast gleich lang, kegelig — walzig, 11. verlängert, walzig, alle Glieder lang, zart, hell behaart.— Prothorax tief gefurcht. Die Furche ist im basalen Teil immer tief und breit, wird nach vorn

schmal, zuweilen linienartig, am Halse wieder grubig vertieft. Punktierung zart und zerstreut, — 3. Furche auf den Elytren durchgehend. 1.— 5. Rippe meist scharf entwickelt, die folgende ganz obliteriert, Rippen und Furchen alle in gleicher Breite.— Beine ohne besondere Merkmale. — Metasternum und die beiden ersten Abdominalsegmente längsgefurcht, Punktierung zart, zerstreut, 3. und 4. Segment fast gleich breit, 5. an den Rändern skulptiert.

Länge (total): 6 mm. *Breite* (Protborax): 1 mm. circa.

Heimat: Ceylon.

2 Stück im British Museum.

Die Art ist nur mit *costatus* Kleine zu vergleichen, von der sie sich folgendermassen unterscheidet: Das Metarostrum ist tief gefurcht, nur die 1.— 5. Rippe sind vorhanden, die folgenden fehlen, Abdomen schmal, tief gefurcht. Bei *costatus*: Metarostrum ungefurcht, alle Rippen deutlich vorhanden, Abdomen breit und flach gefurcht.

TRACHELIZINI.

Trachelizus dividuus n. sp.

♂ Rotbraun, Fühler, Halsring, Hinterrand des Protborax, Sutura, eine grosse postmediane Makel schwärzlich, Beine verdunkelt, am ganzen Körper hochglänzend.— Kopf tief gefurcht, Furche gegen den Hals dreieckig erweitert, ebenso gegen den Rüssel, nur zwischen den Augen gewölbt, einzeln punktiert, Augen sehr gross, rückseitig über den Hals hinausragend, daher auch keine Tuberkeln am hinteren glatten Augenrand, Hinterrand und obere Augenränder stark weissfilzig. - Metarostrum nur mit einer breiten, vollständig filzigen Furche, die am Mesorostrum plötzlich eng wird. Mesorostrum tief und schmal gefurcht, Furche ohne Filz, an den Seiten greift die vom Mesorostrum kommende Filzpartie über, Punktierung einzeln, Prorostrum an der Basis kräftig gefurcht, zart punktiert.— 2.— 8. Fühlerglied perlig, 9. und 10. etwa quadratisch, kugelig - walzig, 11. sehr kurz.— Prothorax tief, durchgehend gefurcht, ohne jede Punktierung. – Elytren mit stark nach vorn vorgezogenem, blattartigem Humerus, 2. Rippe durchgehend, 3. und 4. noch an der Basis entwickelt, auf dem Absturz treten alle wieder hervor, sonst sind dieselben obsolet und durch kräftige Furchenpunktierung erkennbar.— Beine normal.— Metasternum und Abdomen zart punktiert.

Länge (total): 10·0 mm. *Breite* (Prothorax): 2·0 mm.

Heimat: Darjeeling: Gopaldhara, 4,720—6,200 ft. Sammler: H. Stevens.

Typus im British Museum.

Dividuus ist mit *insularis* Senna am nächsten verwandt und nur damit zu vergleichen. Sie unterscheidet sich durch folgende Merkmale: Die tuberkelartigen Verdickungen des Kopfes fehlen gänzlich, das Metarostrum ist nicht nur " a little shorter than the apical one," sondern noch nicht halb so lang. Der Prothorax ist völlig unpunktiert, es fehlt daher jeder Filzbelag. An den Elytren ist der Humerus von ganz auffallender Grösse und Gestalt. Die Ausfärbung der Elytren ist auch anders als bei *insularis*. Es dürfte sich um eine Vicariante dieser Art handeln.

Anocamara catenata n. sp.

♀ Mit *proportionalis* Kln. in den meisten Merkmalen übereinstimmend, aber durch die Form des Kopfes,namentlich unterseits, sicher verschieden. Die Unterseite bildet in der Mitte einen breiten, filzigen Kiel, auf dessen Rändern einzelne, lange Haare stehen. Nach dem Halse zu ist der Kopf halbelliptisch eingekerbt, diese Einkerbung ist mit einem dichten, goldgelben Filz bedeckt und einzeln behaart. Vor den Augen sind die Apophysen gleichfalls dicht filzig behaart. Sonst spiegelglatt. 4.—10. Fühlerglied quer, vom 7. ab mit dichter Unterbehaarung, alle Glieder locker gestellt.

Länge (total): 13 mm. *Breite* (Prothorax): 1·8 — 2·0 mm. circa.

Heimat: Penang.

Typus im British Museum.

Catenata ist habituell gedrungener als *proportionalis*.— Der Gattungs character wird durch die neue Art nur befestigt, da sich die grundlegenden Merkmale wiederholt haben.

Metatrachelizus congruens n. sp.

Mit lockeren Fühlergliedern. Auf den Elytren ist nur noch die 2. Rippe voll entwickelt, alle anderen fehlen, nur die Furchen sind auf der spiegelglatten Fläche als feine Punktierung erkennbar. Am ganzen Körper hochglänzend. Sonst mit *abjectus* Kln. übereinstimmend.

Länge (total): 6·0 mm. *Breite* (Prothorax): 1·0 mm. ca.

Heimat: Assam: Sadiya. Sammler: Doherty.

2 ♂♂ im British Museum.

Hemisamblus gen. nov.

(Wegen des nichtglänzenden Vorderkörpers.)

Kopf länger als breit, bis zu den Augen parallel, hinten flach dreieckig eingebuchtet, oberseits undeutlich gefurcht, platt, Seiten gerade ohne

Zähnchen oder Einkerbungen, Unterseite mit linienartiger Gulargrube; Augen gross, nach vorn gerückt, prominent, der zwischen Auge und Hinterrand liegende Teil so gross wie der Augendurchmesser.– Rüssel schmaler als der Kopf, Metarostrum kürzer als Kopf oder Prorostrum, dreifurchig, Mittelfurche zwischen den Augen tief beginnend, dann verflacht, Mesorostrum weing bucklig, etwas erweitert, basaler Teil so breit wie das Mesorostrum, gefurcht, vorderer Teil breiter, Prorostrum bis zum Vorderrand parallel, basalwärts schräg nach unten scharfkantig abfallend, nach vorn mehr stumpflich, Mittelfurche sehr breit und flach, nur schmale Seitenränder lassend, Vorderrandspartie glatt, Vorderrand flach eingebogen, Unterseite mit einer langelliptisch-rhombischen Einsenkung, die auf Meta - und Prorostrum spitz verläuft; Mandibeln vorstehend, einen kleinen Raum zwischen sich lassend.- Fühler mit keuliger Spitze, 2. Glied sehr kurz, quer, 3.- 8. etwa quadratisch, 9. und 10. vergrössert, kugelig-elliptisch, Spitzenglied konisch, so lang wie das 9. und 10. zusammen.— Prothorax schlank eiförmig, Mittelfurche zart, gegen den Hals verlöschend.-- Elytren schlank, so breit wie der Prothorax, Humerus flach, Hinterrand etwas vorgezogen, alle Rippen voll entwickelt, 1., 2., 3. und 9. den Absturz erreichend, Rippen gerade, schmaler als die Furchen, diese mit flachen Gitterpunkten.— Beine gedrungen, Vorderchenkel breit gestielt, Stiel auf der Oberkante bucklig erhöht, Mittel -- und Hinterschenkel breit gestielt, ohne Buckel, Schienen gerade, ziemlich breit, Tarsen zart, die Glieder etwa gleichlang, Klauenglied schlank, keulig, so lang wie die Tarsen zusammen.— Metasternum durchgehend schmal gefurcht, 1. und 2. Abdominalsegment ungefurcht, 3. Segment länger als das 4., 5. flach gebuckelt.

Typus der Gattung: *Hemisamblus contemptus* n. sp.

Die Plazierung der neuen Gattung ist nicht einfach, weil keine Gattung vorhanden ist an der Anlehnung stattfinden könnte. Eine gewisse Ähnlichkeit besteht im Habitus mit den schlanken *Trachelizus*-Arten, wogegen die Kopfform und der eigenartige Bau des Rüssels sprechen. Der Kopf hat einige Ähnlichkeit mit *Miolispa.* Am besten glaube ich noch die Gattung direkt hinter *Trachelizus* zu stellen, wo sie *Miolispa* zwanglos verbindet.

Hemisamblus contemptus n. sp.

Hellkastanienbraun, Sutura, eine postmediane Makel, Schenkel und Schienen an Basis und Spitze schwärzlich. Kopf und die Thoraxoberseite mit Ausnahme einer schmalen Partie an der Mittelfurche stumpf und matt, sonst hochglänzend.— Kopf einzeln punktiert und in den Punkten behaart, Unterseite ohne deutliche Punkte, länger behaart.— Metarostrum wie der Kopf skulptiert, Meso — und Prorostrum ausser-

halb der Mittelfurche kräftig, zum Teil dicht punktiert und wenig behaart. Metarostrum unterseits wie der Kopf behaart, Mesorostrum sehr dicht, fast zottig behaart, Haare gekrümmt.— Prothorax in der glänzenden Partie an der Mittelfurche grob punktiert, sonst nur sehr zerstreut und zart, Behaarung in den Punkten kurz.— Schenkel in der schwarzen Basalpartie matt, Punktierung und Behaarung spärlich nur am Knie stärker, Schienen wenig skulptiert.— Metasternum und die beiden ersten Abdominalsegmente sehr zerstreut punktiert, 3.—5. Segment dicht chagriniert.

Länge (total) : 10·0 mm. *Breite* (Prothorax) : 1·5 mm. circa.

Heimat : Laos : Vientiane. Sammler R. V. de Salvaza.

Typus im British Museum.

Hypomiolispa conjugalis n. sp.

♂ Schlank, rotbraun, Hinterkopf, Rüsselkanten, Halsring, eine postmediane Makel auf den Elytren und Schenkel und Schienen an Basis und Spitze schwarz; am ganzen Körper glänzend.— Kopf dreieckig, mit den Augen breiter als lang, Hinterrand dreieckig eingekerbt, gewölbt, Mittelfurche sehr zart, Punktierung einzeln, zart, in den Punkten kurz behaart, Seiten mit zwei kurzen, stumpfen Zähnchen. Unterseite einzeln grob, länglich punktiert, Punkte in Reihen stehend; Augen sehr gross, den ganzen seitlichen Kopf einnehmend, fast den Hinterrand des Kopfes berührend.— Metarostrum länger als der Kopf aber kürzer als das Prorostrum, an der Basis schmal, nach vorn breiter gefurcht, Punktierung oberseits und seitlich wie auf dem Kopfe, Mesorostrum mässig erweitert, platt, schmal gefurcht, Prorostrum lang, keilförmig, Kanten rundlich, nach vorn erweitert, an der Basis obsolet gefurcht, Punktierung sehr zart.— 2. Fühlerglied quer, 3. kegelig, 4.-8. etwa quadratisch, scharfkantig, 9. und 10. etwas vergrössert, tonnenförmig, 11. robust, konisch, so lang wie das 9. und 10. zusammen.— Prothorax grob punktiert, die Punkte stehen alle einzeln und werden nach dem Halse zu schwächer, Mittelfurche kräftig.— Elytren und Beine normal.—Metasternum einzeln kräftig punktiert, 1. und 2. Abdominalsegment gefurcht, 5. lang, grubig vertieft, Skulptur des Abdomens wie beim Metasternum.— Parameren messerartig, sehr zart pigmentiert und an der Spitze fast hyalin, Borsten einzeln, gross, an der Spitze und seitl ch. Penis spitzig, nach der Spitze zu an den Seiten verdunkelt. ♀ in üblicher Weise unterschieden.

Länge (total) : 11·0 mm. *Breite* (Prothorax) : 1·0 mm.

Heimat : Andaman Isl. Von Roepstorff gesammelt.

Typus im British Museum.

Habituel besteht grösste Ähnlichkeit mit *denticulata* Kln., von der sie sich leicht dadurch trennen lässt, dass dort die Wangen dreizähnig sind, hier nur zweizähnig. Der Begattungsapparat ist in beiden Arten so verschieden, dass jede Unklarheit ausgeschlossen ist.

Hypomiolispa cruda n. sp.

♂ Von der Gestalt des *Hypomiolispa Helleri*, hellrotbraun Rüssel, Fühler an den Kanten, Halsring, Schenkel an Basis und Knie, eine postmediane Makel auf den Elytren und die erhabenen Rippen seitlich mehr oder weniger schwarz, am ganzen Körper glänzend.—Kopf hinten dreieckig eingekerbt, die Einkerbung setzt sich als Mittelfurche bis zwischen die Augen fort und endigt daselbst in einer grubigen Vertiefung, Skulptur aus einzelnen grossen Punkten bestehend, Augen gross, hinterer Augenrand stumpf zweispitzig, daselbst einige lange Haare, Unterseite am Halsrande mit 3 filzigen Einkerbungen. Skulptur sehr gering.— Metarostrum länger als der Kopf aber kürzer als das Prorostrum, gewölbt, nicht gefurcht, vor dem Mesorostrum mit je einer kurzen, matten Seitenfurche, Punktierung wie auf dem Kopfe, Mesorostrum wenig erweitert, kaum gewölbt, mit schmaler, tiefer Mittelfurche und etwas stärkerer Punktierung, Prorostrum schmal, scharfkantig, noch vorn mässig erweitert, bis ins vordere Viertel breit gefurcht, Punktierung nadelstichig, gegen den Vorderrand dichter.— 9. Fühlerglied quadratisch (ohne Stiel), 3. kegelig, etwas länger als breit, 4.– 5. etwa quadratisch, vom 6. ab mehr breit als lang, 9. und 10. vergrössert, tonnenförmig, 11. stark konisch. alle Gli der lockerstehend.— Prothorax tief gefurcht, an der Basis stark rugos punktiert, gegen den Hals wird die Punktierung schwächer und verschwindet fast ganz.– Elytren normal.— Beine normal, Schienen aller Beine auf der Innenkante dicht kammartig behaart.- Metasternum, 1. und 2. Abdominalsegment zart läng furchig, Skulptur aus einzelnen grösseren und kleineren Punkten bestehend, Apicalsegment dichter punktiert und anliegend behaart. Parameren Abb. 9. Penis =*Helleri*.

Länge (total): 13·0 mm. *Breite* (Prothorax): 2·0 mm. circa.

Heimat: Assam, Patkai, Mts. Aus Sammlung Fry.

Typus im British Museum.

Der Begattungsapparat hat grosse Ähnlichkeit mit *Helleri*, der Penis stimmt fast überein. Der allgemeine Habitus schliesst sich gleichfalls dieser Art an. Was von allen *Hypomiolispa* grundsätzlich trennt ist das gewölbte, ungefurchte Metarostrum. Das hat nur die neue Art. Durch die schwache Punktierung des Kopfes und des vorderen Prothorax, ferner durch den hohen allgemeinen Glanz dieser Organe besteht grosse

verwandtschaftliche Nähe mit *nitida* aus demselben Verbreitungsgebiet. Es liegt hier ohne Zweifel ein Charakteristikum der assamischen Fauna vor.

Hypomiolispa conjuncta n. sp.

♂ Rotbraun, Kanten des Kopfes, Rüssels und der Fühlerglieder, Halsrand, die Elytren in der unten bezeichneten Weise und die Schenkel und Schienen in üblichem Umfang schwarz, am ganzen Körper glänzend. Kopf wenig gewölbt, hinten breit, dreieckig eingekeilt, daraus eine tiefe, schmale, bis vor die Augen reichende Furche entspringend, Skulptur sehr gering, Seiten über den Augen eingekerbt. Wangen mit zwei stumpfen Zähnen. Unterseite flach gewölbt, spiegelglatt. Augen klein, in ⅔ Augendurchmesser vom Hinterrand entfernt. Metarostrum so lang wie der Kopf, flach gefurcht, vor dem Mesorostrum mit kleinen Nebenfurchen, Mesorostrum wenig erweitert, bucklig, tief gefurcht, Prorostrum länger als das Metarostrum, an der Basis flach gefurcht, nach vorn beträchtlich keilförmig erweitert, Punktierung allgemein sehr schwach.— 2., 4.—8. Fühlerglied quer, 9. und 10. etwas kegelig, 9. etwa quadratisch, 10. breiter als lang, 11. kurz, gedrungen, konisch.- Prothorax wie bei der vorigen Art. Elytren mit folgender Zeichnung; durchgehende Verdunkelung der Sutura und des Seitenrandes mit Ausnahme am Humerus und am Absturz, eine Binde antemedian, von der Sutura bis zum Aussenra de, eine postmediane Makel, eine durchgehende Querbinde auf dem Absturz. Beine normal.- Metasternum, 1. und 2. Abdominalsegment gefurcht, 5. grubig vertieft. Punktierung nur auf dem 3.-- 5. Segment dichter und tiefer.

Länge (total): 9·0 mm. *Breite* (Prothorax): 1·25 mm. circa.

Heimat: Tenasserim; Tavoy. von Doherty gesammelt.

Typus im British Museum.

Es gibt keine Art in Gruppe 2 meiner Tabelle,*die so gering skulptiert und auf den Elytren so ausgedehnt geschwärzt wäre. Habituel steht *nitida* Kln. am nächsten, gehört aber in eine ganz andere Gruppe. Verwechselung mit einer anderen Art ist schon durch die Art der Elytrenzeichnung ganz ausgeschlossen. In der Zeichnung besteht Anlehnung an *ceylonica* Desbr.

Hypomiolispa colorata n. sp.

♂ Hellkastanienbraun, glänzend. Elytren mit schwarzer Makel, Hinterranddes Kopfes, Vorderrand des Prorostrums, Vorderkanten der Fühlerglieder, Halsring des Prothorax, Schenkel an Basis und Knie geschwärzt.— Kopf hinten tief dreieckig eingekerbt, mit tiefer Mittel-

* Die Gattung *Hypomiolispa* Kleine Ent. Bl. 14, 1918, p. 76 ff.

furche, gewölbt, einzeln, kräftig punktiert. An den Seiten ist der hintere Augenrand nicht gezahnt, sondern rechteckig eingekerbt, die Einkerbung filzig, Unterseite mit flacher, dreieckiger Gulargrube, die seitliche Filzpartie reicht bis zur Unterseite, Skulptur aus wenigen zarten Punkten und zerstreuten, längeren Haaren bestehend. Augen gross, prominent, in ½ Augendurchmesser vom Hinterrand entfernt. Metarostrum tief gefurcht, scharf skulptiert, nach dem Mesorostrum zu mit stärkerer Punktierung, Mesorostrum wenig erweitert, flach, schmal gefurcht, kräftig punktiert, Prorostrum fast doppelt so lang wie das Metarostrum, nach vorn allmählich breiter werdend, im basalen Teil gefurcht, Skulptur schwach und zerstreut, nach vorn an Dichte zunehmend. 2. Fühlerglied ohne Stiel quer, 3. 8. mehr oder weniger kegelig, nach vorn an Breite zunehmend, 9. und 10. gleich gross, tonnenförmig, 11. konisch, so lang wie das 9. und 10. zusammen. Prothorax eiformigelliptisch, schlank, tief gefurcht, in der basalen Hälfte rugos punktiert, in den Punkten filzig und behaart, nach vorn wird die Punktierung zart und sehr zerstreut; Prosternum sehr fein, nadelstichig einzeln punktiert. Elytren ohne besondere Merkmale. Beine sehr schlank.- Metasternum in den basalen ⅔ gefurcht, an den Seiten und den Hinterhüften kräftig punktiert, 1. und 2. Abdominalsegment breit und flach gefurcht, allgemein stärker punktiert, 3. und 4. Segment mit je einer kräftigen Punktreihe, 5. im basalen Teil glatt, glänzend an den Seiten und am Hinterrande grob punktier und rauh, runzelig.

♀ Nur durch das fadenförmige Prorostrum unterschieden.

Länge (total): ♂ 10·5 mm. ♀ 9 mm. *Breite* (Prothorax): ♂ 1·50 mm. ♀ 1·25 mm.

Heimat: Ceylon: Dikoya, 3,800 1,200 ft. 6. XII. 81- 16.I·82, Bogawantalawa, 4,900—5,200 ft, 28.II.-12. III 82. Sammler: G. Lewis.

Typen im British Museum

Es handelt sich um eine verhältnismässig schlanke Form, die schon stark nach *compressa* hinneigt. In meiner Tabelle kommt man zu *clavata*, mit der sie auch ziemliche Ähnlichkeit hat. Von allen Gattungsverwandten unterscheidet sich *colorata* aber leicht und grundsätzlich dadurch, dass in beiden Geschlechtern die Bezahnung des hinteren Augenrandes fehlt und nur noch durch eine zapfenartige Vorstülpung am unteren Augenrande angedeutet wird. Nun fehlt zwar einer ganzen Gruppe in der Gattung die Bezahnung, aber dann bildet der gerade Augenranddden Hinterrand des Kopfes und das 9.- -11. Fühlerglied ist stark verlängert. Das trifft aber hier nicht zu.

Die Stellung bei *clavata* ist richtig. Es durfte sich um eine endemische Art handeln.

Arairorrhinus conquisitus n. sp.

♂ Rotbraun, glänzend, Rüssel und Fühler an den Kanten, eine undeutliche postmediane Makel auf den Elytren und Schenkel und Schienen an Basis und Spitze verdunkelt.— Kopf fast quadratisch, hinten gerade, kurz, dreieckig eingekerbt, oberseits platt, sehr schmal gefurcht, unpunktiert, Unterseite breit gefurcht.- - Rüssel kurz, Metarostrum etwa 1 ½ mal kürzer als das Prorostrum, gefurcht, nach dem Mesorostrum steil ansteigend, stumpfkantig, Mesorostrum nicht erweitert, ungefurcht, vom Metarostrum scharf abgesetzt, Prorostrum nach unten gebogen, parallel, stumpfkantig, ungefurcht, zart punktiert, Unterseite wie der Kopf breit gefurcht, vom Mesorostrum ab mit zartem Mittelkiel. 2., 4 8. Fühlerglied fast quadratisch, 3. kegelig, Kanten rundlich, 9. und 10. rundlichwalzig, fast kugelig, 11. konisch, so lang wie das 9. und 10. zusammen.- - Prothorax eiförmig, gefurcht, Furche nach vorn zarter werdend, sehr zart punktiert, am Halse dichter und tiefer.- 2. Rippe auf den Elytren etwas niedriger als alle anderen, Hinterrand stumpfeckig.- Schenkel aller Beine breit, Vorderschienen sehr kurz, innen mit Haarbüschel, Mittel- und Hinterschienen länger. Tarsen normal.- Metasternum, 1. und 2. Abdominalsegment gefurcht, 5. Segment grubig vertieft.

Länge (total) : 6 mm. *Breite* (Prothorax) : 1·2 mm. circa.

Heimat : Perak. Sammler : Doherty.

Typus im British Museum.

Trotz der etwas abweichenden Gestalt glaube ich doch, dass es am besten ist, die Art in der Gattung zu belassen. Die wichtigsten Merkmale finden sich wieder. Von allen bekannten Arten trennt : 1. der Rüssel, insofern, als das Prorostrum nicht rund sondern kantig und nur 1 ½ mal so lang ist als das Metarostrum. Bei den anderen Arten ist es meistens 3 - 4 mal so lang. Die Unterseite von Kopf und Rüssel ist breit gefurcht. Der Prothorax ist am Halse mehr verengt. Die Schenkel sind breiter und die Vorderschienen sehr kurz.

Araiorrhinus Beesoni n. sp.

Kastánienbraun, die Sutura etwas verdunkelt, keine Makel auf den Elytren, stark glänzend, Furche des Prothorax und die Furchen oberseits auf den Elytren schwach filzig. - Kopf am Hinterrand in der Mitte flach eingekerbt, Oberseite glatt, undeutlich punktiert, hinterer Augenrand knotig verdickt. — Metarostrum platt, ungefurcht, erst dicht vor dem Mesorostrum beginnt die Furche breit, und setzt sich breit über dem Mesorostrum bis auf das Prorostrum fort, verschwindet aber sehr bald.— 3.—8. Fühlerglied gleichgross und von gleicher Gestalt, perlig

breiter als lang, 9. und 10. vergrössert, 9. fast noch quadratisch, 10. etwas länger als breit.— Prothorax durchgehend tief und breit gefurcht. Punktierung sehr zart und undeutlich, seitlich hinter dem Halse eine matte Stelle.— 2. Rippe auf den Elytren weit unterbrochen, die folgenden wellig, Rippen breiter als die Furchen, an den Seiten ebenso scharf als oberseits.

Länge (total): 6 mm. *Breite* (Prothorax): 1·0 mm. circa.

Heimat: Mohnyin Res. Katha, Burma, 23. V. 1919. Von Dr. C. F. C. Beeson gesammelt.

Typus im Forest Research Institute, Dehra Dun.

Vier Arten sind bisher aus dem orientalischen Gebiet bekannt, alle von Sumatra. Von diesen scheiden *exportatus* Senna, *australicus* Senna und *sondaicus* Senna aus, da bei denselben, wie Senna selbst angibt, die 2. Rippe nicht unterbrochen ist. Für *longirostris* Senna ist das aber nicht direkt angegeben. Diese Art ist indessen leicht zu trennen, weil bei ihr der Prothorax nur an der Basis und auch da nur sehr zart gefurcht ist. Ausserdem sollen die Rippen nur leicht wellig gebogen sein. Das spricht dafür, dass die 2. Rippe nicht unterbrochen, ja, nicht einmal verschmälert ist. Die neue Art ist also gesichert.

Tulotus maculipennis Senna.

Ann. Soc. Ent. Belg. 1894, XXXVIII, p. 371.

Senna hat nur den ♂ gesehen. Ich fand 4 ♀♀ im Material des Britischen Museums. Die Geschlechter sehen sich äusserst ähnlich, da die bei Brenthiden sonst häufige Rüsseldimorphie gänzlich fehlt. Das ♀ ist in folgenden Merkmalen vom ♂ unterschieden: Fühler gedrungen, 2.- 10. Glied quer, viel breiter als lang, locker stehend, 11. konisch, so lang wie das 9. und 10. zusammen. 1. und 2. Abdominal segment ungefurcht, gewölbt.

Typus im British Museum.

Die Fühler können sich zuweilen der männlichen Form nähern, auf jeden Fall ist das Abdomen beim ♀ immer gewölbt und ungefurcht, sonst genau mit dem ♂ übereinstimmend. Ausser Birmah (Ruby Mines) demselben Fundort aus dem Sennas Stücke stammten, fand ich noch: Assam und Ost-Indien: Manipur.

Microtrachelizus beneficus n. sp.

♂ Rotbraun, mässig glänzend, Elytren fast stumpf, Halsrand, eine postmediane Makel auf den Elytren und die Schenkel an Basis und

Knie schwarz.— Kopf am Hinterrande in der Mitte dreieckig eingekerbt, dann schmal gefurcht, Furche nach dem Prorostrum zu erweitert, einzeln punktiert, in den Punkten kurz behaart. Seiten hinter den Augen zapfenartig erweitert.— Metarostrum dreifurchig, Mesorostrum erweitert, flach, so tief und breit wie das Metarostrum, gefurcht, Prorostrum in der basalen Hälfte tief gefurcht, Skulptur und Behaarung bis zum Vorderrande in gleicher Stärke wie auf dem Kopf.— Prothorax durchgehend gefurcht, einzeln aber deutlich punktiert und in den Punkten kurz, anliegend behaart.— Humerus der Elytren vorgezogen, 3., 4. und 5. Rippe an der Basis scharf aufgekielt. 2. Rippe zwar auf der Mitte verengt, aber nicht unterbrochen.

Länge (total): 5–6 mm. *Breite* (Prothorax): 1·25 mm—1·5 mm. 10 Exemplare.

Heimat: Margherita, Lakhimpur Division, Assam 22. XI. 1921. [Bred at Dehra Dun from log of *Shorea assamica* C.F.C.B.]

Die neue Art gehört in die kleine Gruppe derjenigen Arten, deren Metarostrum dreifurchig ist. Von den in näherer Konkurrenz stehenden Arten: *accomodatus* Kleine und *tabaci* Senna hat letztere die 2. Rippe nur in der apicalen Hälfte entwickelt, an der Basis fehlt sie ganz. Bei *beneficus* ist Rippe 2 aber vollständig vorhanden, wenn sie auch in der Mitte verschmalert ist. Ferner habe ich bei keiner anderen Art den hinteren Augenrand so verdickt gefunden. Die Trennung ist also leicht und sicher.

Microtrachelizus apertus n. sp.

♂ Mit *tabaci* Senna am nächsten verwandt. Kopf am Hinterrand tief dreieckig eingekerbt, ohne jede Furche, gewölbt, eine zerstreute mehr oder weniger deutliche Punktierung tragend. Meta-, Meso- und Prorostrum im basalen Teil tief gefurcht. Mittlere Fühlerglieder quer, scharfkantig. Prothorax zart punktiert, 2. Rippe auf den Elytren nur am Absturz vorhanden.

Lange (total): 5 mm. *Breite* (Prothorax): 0·75 mm.

Heimat Borneo: Sandakan. Von Baker gesammelt; Penang, Brit. Mus. Assam: U. Dihing Res. Lakhimpur; Nambor Res., Sibsagar, aus Coll. Bees n 5. 6. 21.

Typen in der Sammlung des Forest Research Institutes zu Dehra Dun und im Dresdener Museum.

Von *tabaci* ausser durch den ungefurchten Kopf noch durch die ganz andere Anordnung der Platte auf dem 5. Abdominalsegment gekennzeichnet. Die Vertiefung der Platte ist nicht rund und tief, sondern elliptisch und flach. Die Punktierung am ganzen Körper ist äusserst wechselnd und kann zuweilen ganz fehlen.

AMORPHOCEPHALINI.

Paussobrenthus conterminus n. sp.

♂ Robust, violettbraun, hochglänzend, Ränder an Kopf, Rüssel, Halsring, Schenkel und Schienen an Basis und Spitze schwarz.— Kopf sehr obsolet dreieckig vertieft, dem Metarostrum gegenüber ein kammartiger Kiel, Augenränder erhöht, Punktierung einzeln, an den Augenrändern stärker, ebenso in der Vertiefung am Rüssel, in den Exsudatporen überall behaart, Unterseite mit einzelnen behaarten Exsudatporen, Augen den ganzen seitlichen Kopf einnehmend.— Apophysen des Metarostrums gross, in der Mitte vertieft und mit dichten, behaarten Exsudatporen besetzt. Schild des Metarostrums gross, nach hinten erweitert, spiegelblank, nur einzelne Exsudatporen vorhanden, die auf der Rüsselkante dichter stehen, grösser sind und Haare tragen. Prorostrum rundlich, im basalen Teil gefurcht, einzeln punktiert. – Fühler gleich *Bakeri* Gestro.—Prothorax mit einzelnen zerstreuten Exsudatgruben und kurzer Behaarung.— Elytren sowohl in den Furchen wie auf den obsoleten Rippen zart punktiert und behaart. Beine normal aber überall mit grossen behaarten Exsudatgruben ziemlich dicht besetzt. Metasternum und Abdomen nicht gefurcht, einzeln aber kräftig punktiert und behaart.

Länge (total): 12·0 mm. *Breite* (Prothorax): 2·0 mm.

Heimat: Cambodia.

Typus im British Museum.

Die neue Art ähnelt mehr einen *Leptamorphocephalus*. Während *Bakeri* und *concitatus* dicht pruinos skulptiert sind, ist *conterminus* ausgesprochene spiegelglatt. Jene beide Arten tragen keine Exsudatorgane mehr und sind ausgeprochene Räuber, die neue Art dagegen ist noch mehr oder weniger der Symphilie angepasst. Die überall vorhandenen Exsudatporen beweisen das. Im übrigen ist der Trutztypus der Gattung vollständig ausgeprägt und wird die von Gestro aufgestellte Diagnose nicht beeinträchtigt. Es zeigt sich nur, dass die biologischen Charactere in der Gattung keineswegs einheitliche sind.

Paussobrenthus concitatus n. sp.

♀ Habituell mit *Bakeri* Gestro übereinstimmend aber durch die Gestalt des Kopfes verschieden. Während bei *Bakeri* der Kopf gegen das Metarostrum dreieckig vorgezogen ist und in seiner Mitte eine tuberkelartige Erhöhung trägt (Capo.... ....in avanti triangolarmente per adattarsi alls base escavata del rostro; su questa sporgenza esiste un piccolo tuberculo elevata, rotondeggiante........ bei Gestro), ist bei *concitatus* der Kopf vom Metarostrum durch die zwischen den Organen liegende Einsenkung getrennt und nicht nach vorn dreieckig vorgezogen.

Die tuberkelähnliche Erhöhung fehlt vollständig, die bei *Bakeri* weit nach vorn stehenden Augen sind klein, bei *concitatus* dagegen sehr gross, in höchstens ½ Augendurchmesser vom Hinterrand des Kopfes entfernt. Ferner bestehen im Bau des Rüsselschildes, wenn die Abbildung bei Gestro richtig ist, wichtige Differenzen. Bei *Bakeri* endigt der Schild nach vorn zungenförmig verschmälert, bei *concitatus* ist er fast kreisförmig abgerundet. Durch die Gestalt des Kopfes besteht nicht unbedeutende Anlehnung an die Gattung *Cordus*, ich halte es aber, bevor der Mann vorliegt für besser, *concitatus* bei *Pasussobrenthus* zu belassen, schon wegen des eineihtlichen Gesamthabitus.

Länge (total) : 9·0 mm. *Breite* (Prothorax) : 1·5 mm. circa.

Heimat : Andaman Isl.

Typus im British Museum.

Leptamorphocephalus cuneatus n. sp.

♂ Kirschrot, Halsring, Rüssel an den Kanten, Fühlerglieder vorn, Schenkel an der Basis, weniger am Knie, schwarz, am ganzen Körper hochglänzend, unbehaart. - Kopf in üblicher Weise in der Mitte vertieft, am inneren Augenabsturz einzelne Exsudatgruben mit wechselnd langer Behaarung, mittlere Partie unbehaart, unpunktiert, Unterseite mit einzelnen Punkten, in denselben anliegend je ein Haar. Augen gross, mässig prominent, nach unten halbelliptisch, Oberkante abgestutzt.—Apophysen des Metarostrums spatelförmig, durch einen schmalen Stiel mit dem Rüssel verbunden, Skulptur und Behaarung sehr gering. Rüsselaufsatz schildförmig, hinten stark eingebuchtet, seitlich flach geschwungen, oberseits spiegelglatt mit einzelnen feinen Punkten, seitlich chagriniert, mehr rauh, Prorostrum sehr schmal, nach unten zu schräg verbreitert, gegen den Vorderrand zunächst verschmälert, dann wieder etwas verbreitert, bis vorn gefurcht, Vorderrand sehr schmal, in der Mitte nach innen gebuchtet, Prorostrum in der vorderen Partie mit backenartigen Erweiterungen, die an ihren hinteren Kanten borstig, abstehend behaartsind, Unterseite gerundet, am Vorderrand kaum etwas verdickt. - 4. —8. Fühlerglied etwas quadratisch, nach vorn an Länge zunehmend,9. und 10. walzig, 11. so lang wie das 9. und 10. zusammen, vorn sehr spitz, Glieder nicht nodos, locker stehend. - Prothorax ungefurcht, nur zerstreut und sehr zart punktiert.—Elytren gerippt-gefurcht, Rippen schmal, scharf, Furchen breit, 8.— 10. Rippe an den Seiten obsolet, Punktierung in den Furchen kaum wahrnehmbar.—Beine sehr schlank, sonst ohne besondere Merkmale.—Metasternum nur an der Basis grubig vertieft, Abdomen ungefurcht, Skulptur der Körperunterseite äusserst zart und zerstreut, 5. Abdominalsegment seidig behaart.

Länge (total) : 10·0 mm. *Breite* (Prothorax) : 1·6 mm. circa.

Heimat: Assam, Patkai Mts. Sammler: Doherty, aus Sammlung Fry.

Typus im British Museum.

Die neue Art ist durch die Bildung des Prorostrums von allen andern grundsätzlich verschieden. Die beborsteten Anhänge müssen als Träger der Exsudatorgane angesehen werden. Mit Ausnahme des inneren Augenabsturzes fehlt jede Spur dieser Organe, eine ganz ähnliche Bildung kommt in der Gattung *Micramorphocephalus* vor und ist auch dort als Träger der Exsudatorgane aufzufassen.

Leptamorphocephalus cupidus n. sp.

♂ Kastanienbraun, glänzend.— Kopf bis in die tiefsten Partieen mit einzelnen behaarten Exsudatgruben, Unterseite einzeln punktiert und anliegend behaart, Augen gross, wenig prominent, nach unten halbelliptisch, Oberkante flacher.— Apophysen des Metarostrums blattartig, nach vorn zu stielartig verschmälert, einzeln punktiert und lang behaart, Rüsselaufsatz schildförmig, hinten tief eingebuchtet, in der Grundgestalt etwa quadratisch, Seiten mehr oder weniger grade, keine Mittelfurche, Exsudatgruben nur an den Rändern, Behaarung in denselben kurz, auf der Oberseite sehr zerstreut und fein punktiert, Prorostrum an den Fühlern stark verengt, dann erweitert aber viel schmaler als der Kopf, oberseit sehrs schmal, scharfkantig, tief gefurcht, nach unten breit, schräg abfallend, Vorderrand in der Mitte etwas vorgebogen, Unterseite wie der Kopf skulptiert, am Prorostrum elliptisch erweitert, in der Mitte schmal vertieft, in der Vertiefung eine nach hinten gerichtete zungenartige Vorstülpung, Mandibeln kräftig. 3. Fühlerglied kegelig, so lang wie das 9., 4.—8. walzig, länger als breit, 9. und 10. von gleicher Gestalt, verlängert, 11. schlank, so lang wie das 9. und 10. zusammen, alle Glieder locker stehend, lang behaart.— Prothorax elliptisch, gewölbt, mit zerstreuten, behaarten Punkten.— Elytren gerippt-gefurcht, 2. Rippe am Absturz unterbrochen, bis zur 7. alle scharf erhaben, von der 8. ab verschwommen, 2, 3, 7. durchgehend, 8. nur am Absturz deutlich, keine Rippe verkürzt, Furchen breit, unpunktiert.— Beine normal.— Metasternum und die beiden ersten Abdominalsegmente gefurcht, 4. kürzer als das 3., 5. flach abgeplattet, hinten seitlich zusammengedrückt, am Hinterrande unten gebogen. Punktierung allgemein äusserst zart, kaum sichtbar, Apicalsegment an den Seiten etwas dichter.

Länge (total): 11·0 mm. *Breite* (Prothorax): 1·6 mm. circa

Heimat: India. Aus Sammlung Fry.

Typus im British Museum.

In allen grundsätzlichen Eigenschaften stimmt die neue Art mit der Gattungsdiagnose überein, so dass die Zugehörigkeit ausser Zweifel ist.

Während alle anderen *Leptamorphocephalus* arten ein Prorostrum haben, dass nach unten wenig erweitert ist und dadurch einen schmalen Vorderrand hat, ist dasselbe hier auffällig verbreitert. Es ist also eine beträchtliche Annäherung an die *Amorphocephalus* arten erkennbar. Innerhalb der Gattung scheint mir *laborator* Kln. am nächsten zu stehen, es ist aber nur das ♀ bekannt. Eine Collission mit jener Art ist nicht zu befürchten, weil bei *cupidus* keine Rippen auf den Elytren verkürzt sind, bei *laborator* dagegen mehrere.

Amorphocephalus delicatus n. sp.

♀ Dunkel violettbraun, die üblichen schwarzen Körperteile sich wenig von der dunklen Grundfarbe abhebend, Glanz mässig.— Dem *coronatus* Germ. am ähnlichsten, Kopf wie bei jener Art, die über den Augen liegenden Furchen tief, hinten offen, die hinteren Kanten über den Augen stark erhaben, Punktierung und Exsudatgruben fehlen, Unterseite unpunktiert. Apophysen gross, zungenförmig, fest mit dem Metarostrum verbunden und keinen Zwischenraum frei lassend. Schild des Metarostrums ein hinten abgestumpftes Dreieck bildend, hinten breit dreieckig eingekerbt, die Einkerbung in eine Furche ausgehend. In diesem Teil ist der Schild stark gewölbt, vordere Hälfte platt, Mittelfurche ganz obsolet, Exsudatgruben fehlen, nur an der hinteren Einbuchtung mit filzigen Haarbuscheln. Prorostrum rundlich, schwach skulptiert. 1. Fühlerglied gross, klobig, 2. ohne Stiel breiter als lang, 3. kegelig, etwas länger als breit, 4—8. walzig, die vorderen Glieder nach aussen etwas eingekerbt, 9. und 10. nicht verbreitert, aber erheblich länger als die vorigen, 11. sehr schlank, lang zugespitzt. Alle Glieder locker stehend, nur die drei Spitzenglieder lang grubig skulptiert, die übrigen Glieder sind nur auf der Innenseite wenig behaart und schwach skulptiert. Prothorax breit und flach, allgemeine Punktierung zart, nur am Hinterrand jederseits der Mitte eine langdreieckige, tiefpunktierte Partie. 2. und 3. Rippe breiter als die folgenden.— Beine normal.

Länge (total): 13·0 mm. *Breite* (Prothorax): 3·0 mm.

Heimat: Karachi, India. Sammler T. R. Bell, 3. 4. 1904.

Obwohl es sich um eine indische Art handelt, gehört *delicatus* doch bestimmt zu *Amorphocephalus*. Es sind bisher nur afrikanische Arten bekannt, dort liegt das Entstehungszentrum. Nördlich ist die Gattung am ganzen Mittelmeer verbreitet und dringt östlich bis zum Kaukasus vor. Hier verlieren sich die Spuren, und es treten im Osten andere Gattungen auf. In Ostindien selbst leben nur wenige Arten der Gattung *Leptamorphocephalus*. Die Feststellung der neuen Art ist insofern von grösster Wichtigkeit, als dadurch bewiesen wird, dass *Amorphocephalus*

tatsächlich nach Osten vorgedrungen ist und die östlichen Formen davon abgeleitet sind. Es ist nicht unmöglich, dass in Persien und Belutschistan die Gattung ebenfalls vertreten und nur noch nicht aufgefunden ist. Karachi dürfte vielleicht der östlichste Punkt sein, den *Amorphocephalus* erreicht hat. Es scheint mir auch kein Zufall zu sein, dass *delicatus* dem *coronatus* am ähnlichsten steht, denn diese Art ist die einzige, die weit nach Osten geht. Jedenfalls ist die neue Art einer der zoogeographisch wichtigsten Funde, die ich kennen gelernt habe.

[A second specimen of *delicatus*, a male, was taken by T. R. Bell also in Karachi on 2, April 1905, C. F. C. B.]

ARRHENODINI.

PERORYCHODES n. gen.

♂ Kopf breiter als lang, Hinterrand breit und tief dreieckig eingekerbt, in der Mitte der Einkerbung eine zapfenartige Vorstülpung zwischenden Augen quereingedrückt, dann wieder erhöht und in eine breite, tiefe Mittelfurche übergehend, hintere Augenkanten sehr scharf, Gulareindruck auf der Unterseite sehr klein, unter den Augen eine grobe Punktureihe, Augen gross, fast den ganzen seitlichen Kopf einnehmend. Metaros-trum länger als der Kopf aber kürzer als das Prorostrum, tief gefurcht, nach dem Mesorostrum zu verflachend, Seiten wellig, Unterseite gekielt, Punktierung wie auf dem Kopfe, keine Apophysen, Mesorostrum flachmässig erweitert, schmal gefurcht, Furche nach dem Prorostrum erweitert, Prorostrum an der Basis schmal, kantig, nach vorn wenig erweitert und nur am Vorderrand mit runden Kanten, Ränder nur mässig gedornt, aber durchgängig warzig skulptiert, Mandibeln klein, Fühler gedrungen den Prothorax nicht überragend, 1. Glied gross, keulig, 2. fast quadratisch, 3. und 4. kegelig, 5.- 8. mehr zylindrisch, unter sich fast gleichlang 9. and 10. von gleicher Form, etwas länger, 11. schlank, so lang wie das, 9. und 10. zusammen, alle Glieder locker stehend, nach vorn mit zunehmender Behaarung.-- Prothorax eiförmig, ungefurcht, gewölbt, Prosternum gewölbt.-- Elytren an der Basis gerade, nach dem Absturz zu allmählich verschmälert, Hinterecken rundlich, gitterfurchig, mit Schmuckzeichnung.-- Beine schlank, Vorderbeine am grössten, Vorderschenkel robust, mit auffallend langem Dorn auf der Mitte, Mittel, und Hinter-schenkel kurz gedornt, schlank, Vorderschienen gekrümmt, im vorderen Drittel stumpf erweitert, nicht gedornt, die übrigen Schienen gerade, schlank, Tarsen ohne besondere Merkmale.- Metasternum schmal und tief gefurcht. 1. und 2. Abdominalsegment breit und flach gefurcht, letzteres hinten schmal, leistenartig abgesetzt. Quernaht tief, 3. Segment länger als das 4, 5. stark borstig behaart.

Typus der Gattung : *P. Arrowi* n. sp.

Die neue Gattung gehört in die *Orychodes*—Verwandtschaft und zwar zur Gruppe derjenigen Gattungen, deren Vorderschienen gekrümmt sind. Wenn die bei *Caenorychodes* Kln. und *Henorychodes* Kln. vorhandenen starken Schienendorne auch fehlen, so ist diese Stelle doch stark vorgewölbt und lasst den Dorn als stumpfe Erweiterung erkennen. Von *Orychodes* trennen die gegitterten Elytren, von *Henorychodes* der ganz andere, seitlich nicht erweiterte Kopf. Die Gestalt desselben ist überhaupt so appart wie ich ihn noch bei keiner anderen Gattung des Tribus gesehen habe.

Perorychodes Arrowi n. sp.

Violettbraun, glänzend, Elytren schwarz, matt, Schmuckzeichnung blutrot, Skulptur auf Kopf und Rüssel aus zerstreuten Punkten bestehend. Prorostrum warzig skulptiert. Prothorax äusserst fein zerstreut punktiert. Lage der Schmuckzeichnung : 3. Rippe kurzer Streifen basal, ante und postmedian und apical, 4. je ein kuzer Streifen ante- - und postmedian, 5. postmedian. 6. ein kurzes Streifchen im vorderen Drittel und postmedian, 8. und 9. je eine Posthumerale, letztere auch mit kurzem Apicalstreifen. Metasternum wie der Prothorax skulptiert. Abdomen etwas stärker.

Länge (total) : 20 mm. *Breite* (Prothorax) : 4·0 mm.

Heimat : India ; Allahabad.

Ich widme diese schöne Art Herrn Dr. Arrow in London, für seine uneigennützigen Bemühungen und Unterstützungen meiner Studien.

Hemiorychodes dissonus n. sp.

♂ Hellrotbraun, Elytren etwas dunkler, Schmuckzeichnung hellgelb, auf den Elytren postmedian eine schwärzliche Makel, Prothorax und Kopf ganz matt, Elytren mässig, Metasternum, Abdomen und Beine stark glänzend. Kopf gewölbt, flach gefurcht, einzeln zart punktiert, einzeln lang behaart, Unterseite mit grober Punktreihe unter den Augen, in den Punkten einzeln behaart, keine zottige Behaarung. Metarostrum gefurcht, seitlich vor den Augen mit mehreren grossen Punkten, Unterseite wie der Kopf grob punktiert, überall wie auf dem Kopf mit einzelnen Haaren, Mesorostrum bucklig erhöht, Mittelfurche so breit wie auf dem Kopfe, scharfkantig, Prorostrum oberseits schwach gezahnt, vorn warzig skulptiert. Meso-und Prorostrum unterseits an den Kanten dicht behhaart.-- 3. -- 8. Fühlerglied etwa gleichlang, die basalen kegelig, nach vorn zu mehr walzig, 9. und 10. walzig, etwas länger als die vorhergehenden, 11. lang zugespitzt, so lang wie das 9.

und 10. zusammen, alle Glieder locker stehend, kräftig behaart.— Prothorax einzeln und sehr zart punktiert, in den Punkten anliegend behaart. — Elytren seitlich parallel, gegen den Absturz allmählich verschmälert, hintere Aussenecken stumpfspitzig, 1.—3. Rippe breit und flach, die folgenden schmal, aufgewölbt, 1—3. Furche schmal, Punktierung klein, die folgenden Furchen breit, gegittert. Lage der Schmuckzeichnung: 3. Rippe je ein Streifen postmedian und apical, 4. je ein mittellanger Streifen postbasal und median, ein kurzes Streifchen postmedian, 5. kurzer Basalstreifen und desgl. postmedian, 6. kurzer Streifen antemedian, 7. mittellanger Streifen postmedian, 8. langer posthumeraler und kurzer Streifen postmedian, 9. kurze Posthumerale und Apicale.—Beine normal.- Metasternum und Abdomen nur sehr zart punktiert, 2.—5. Segment an den Seiten dicht behaart.

♀ nur durch das stielrunde Prorostrum unterschieden,

Länge (total): ♂♀ 11—12 mm. *Breite* (Prothorax): 2·0 mm. circa.

Heimat: Perak, Sammler: Doherty. Aus Coll. Fry.

Typen 1♂, 3 ♀♀ im British Museum.

Habituell mit *cambodjensis* Kln. am nächsten verwandt, zunächst durch die ganz andere, übrigens durchaus konstante Schmuckzeichnung verschieden. Der Begattungsapparat ist aber ganz anders geformt und ähnelt mehr *modestus* Kln., mit der auch durch das behaarte Prosternum Gemeinschaft besteht. Es ist also auf die Schmuckzeichnung zu achten. Es dürfte sich um eine Variante von *modestus* handeln. Die schwarze Makel auf den Elytren kann sehr schwach werden oder ganz fehlen.

Hemiorychodes curvus n. sp.

♂ Prothorax, Kopf und Rüssel violettbraun, heller bis tiefschwarzbraun matt, Elytren schwarz, glänzend, Schmuckzeichnung hellrotgelb, sich scharf von der Grundfarbe abhebend. Unterseite rotbraun Beine desgleichen, hochglänzend.– Kopf oberseits einzeln punktiert, über den Augen und auf dem Metarostrum seitlich anliegend kräftig behaart, Mittelfurche deutlich, die Punktierung auf der Unterseite mit je einem Haar im Punkt.- Metarostrum breit gefurcht, sehr einzeln, zart punktiert, Seiten und Unterseite wie die Kopfunterseite beschaffen, Mesorostrum halbrund, seitlich erweitert. Aussenränder aufgebogen, die vom Metarostrum kommende Mittelfurche nur bis zur Mitte reichend, dann scharf abgebrochen, an der Abbruchstelle bucklig verdickt, Prorostrum mit kräftigen Zähnen auf den Seitenkanten im Basalteil, sonst mit warziger Skulptur, Unterseite lang zottig behaart.— 2. 5. Fühlerglied kegelig, die folgenden walzig, alle Glieder locker stehend.- Prothorax äusserst zart punktiert, sehr undeutlich, in den Punkten einzeln, anliegend kurz behaart, im basalen Teil mit undeutlicher Mittelfurche.- Lage der

Schmuckzeichnung auf den Elytren : Rippe 3 je ein kleiner Streifen post median und apical, 4 ein kurzer Streifen postbasal, ante — und postmedian, 5 basal und postmedian, 6 je ein Punkt ante — und postmedian von denen der vordere fehlen kann, 7 kleiner Streifen postmedian, 8 posthumeral, 9. desgleichen und apical, 2. und 3. Rippe auf der Mitte bis gegen den Absturz platt, breit, sonst normal tief gitterfurchig, hintere Aussenecken stumpflich zugespitzt. Beine normal. – Unterseite des Körpers sehr zerstreut und zart punktiert.

Länge (total) : ♂ ♀ 11—16 mm. *Breite* (Prothorax) : ♂ ♀ 2—3 mm.

Heimat : India. Manipur ; Burma, Ruby Mines, Perak. Sammler : Doherty.

Typen im British Museum.

Von den bekannten Arten durch den Begattungsapparat getrennt. Von *cambodjensis* durch die behaarten oberen Augenränder, von *modestus* durch die helle Schmuckzeichung verschieden. Von beiden Arten durch die ganz andere Anlage der Schmuckzeichnung leicht zu trennen.

Die Variationsbreite ist ziemlich beträchtlich. Sie erstreckt sich auf Grösse und Ausfarbung, weniger auf die Skulptur. Ganz unberührt von der Variation bleibt die Schmuckzeichnung.

Die bisher bekannten Arten stammen von Cambodia, *cureus* schliesst sich dem ungezwungen an und erreicht in Br. Indien die Westgrenze.

Hemiorychodes contexta n. sp.

♀ Hellviolettbraun, mässig glanzend.- Kopf, Meta-und Mesorostrum kräftig punktiert, fast grubig, Unterseite nicht zottig behaart, überhaupt ohne jede Behaarung, Prorostrum stielrund, glatt.— Fühler normal.— Prothorax nur zerstreut punktiert. 2. Rippe der Elytren schmaler als die 3. Gitterung tief rugos. Rippen rundlich. Lage der Schmuckzeichnung : Rippe 3 langer Basalstreifen, kürzerer postmedian und apical, 4 je ein kurzer ante und postmedian, 5 kleiner Basalfleck desgleichen antemedian vor dem Streifen auf 4 und postmedian, 6 postmedian ein kleiner Streifen, 8 Posthumerale, 9 kurzer Apicalstreifen, Hinterrand winklig. Beine normal, Vorderschenkel und Schienen kurz behaart. Metasternum nur an der Basis eingedrückt. Abdomen ungefurcht, Punktierung einzeln aber kräftig.

Länge (total) : 15·0 mm. *Breite* (Prothorax) : 2·5 mm.

Heimat : Cambodia.

Typus im British Museum.

Die neue Art unterscheidet sich von allen anderen durch den stark glänzenden Prothorax, durch das Fehlen jeder Behaarung auf der Unterseite des Kopfes und Rüssels, ferner durch die starke Skulptur des ersteren und durch die ganz andere Anlage der Schmuckzeichnung.

Hemiorychodes continens n. sp.

♂ Dunkelviolettbraun, Schmuckzeichnung schmutziggelb. Glanz sehr mässig.—Kopf zwischen den Augen mit obsoleter Furche, einzeln punktiert und in den Punkten kurz behaart. Unterseite mit je einer groben Punktreihe, in den Punkten behaart. Metarostrum tiefgefurcht, an den Seiten mit einzelnen grossen groben Punkten und kräftiger Behaarung, Unterseits wie beim Kopf. Mesorostrum verbreitert aber flach, Furche verschmälert, Unterseite gekielt, an den Seiten zottig behaart Prorostrum erweitert, basal mit dornigen, zackigen Rändern, Skulptur, warzig, Unterseite nicht behaart, nadelstichig punktiert. 2. Fühlerglied kurz, 3. lang, kegelig, so lang wie das 9. oder 10, 4. von ähnlicher Form aber kürzer, 6. und 8. walzig, etwas länger als breit, 9. und 10. nicht verbreitert aber verlängert, 11. lang, konisch, wenigstens so lang wie das 9. und 10 zusammen, alle Glieder mit grober Skulptur und locker stehend. Prothorax zart und einzeln punktiert und kurz behaart. Elytren am Hinterrande flach eingeschnitten, Lage der Schmuckzeichnung: Rippe 3 basaler Punkt, Streifen median, postmedian und apical, 4 lang basal, kurz median und postmedian, 5 mittellang, basal, sehr kurz antemedian, mittelang postmedian, 6 ante und postmedian, 7 kurz ante und mittelang postmedian, 8 posthumeral und postmedian, 9 basal, posthumeral, apical. Beine normal. Unterseite mässig punktiert, 3. 5. Abdominalsegment an den Seiten behaart.

Länge (total): 16·0 mm. *Breite* (Prothorax): 2·5 mm.

Heimat: Penang.

Typus im British Museum.

Von den bisher bekannten Arten ist *modestus* Kl. auf der Unterseite des Rostrums zottig behaart. Die Trennung ist durch die ganz veränderten Anlagen der Schmuckzeichnung leicht gegeben.

Pseudorychodes damnosus n. sp.

♂ Kastanienbraun in wechselnder Tiefe, Halsring, Hinterrand des Kopfes, Rüssel und Fühlerglieder an den Kanten, Schenkel und Schienen an Basis und Spitze mehr oder weniger verdunkelt, Schmuckzeichnung schmutzigrotgelb, wenig von der Grundfarbe abstechend, Glanz am ganzen Körper mittelstark.—Kopf breiter als lang, Hinterrand gerade, Aussenecken stumpfkantig, Oberseite gewölbt, ungefurcht, mit Ausnahme einer Mittellinie kräftig punktiert, in den Punkten anliegend behaart, Unterseite mit tiefer Gulargrube und 1-2 Reihen grober Punkte, in den Punkten je ein Haar stehend, Augen sehr gross, prominent.—Metarostrum gegen das Mesorostrum wenig verengt, Mittelfurche an den Augen flach keilförmig beginnend, nach dem Mesorostrum zu mit stark erhabenen

kielartigen Rändern, so dass die Furche sehr tief wird, Skulptur mit Aussahme der Mittelinie aus einzelnen kräftigen und behaarten Punkten bestehend. Auf dem Mesorostrum setzen sich die erhabenen Furchenkanten fort, verflachen dann etwas, Mittelfurche verschmälert, seitliche Erweiterungen platt, halbelliptisch, Skulptur und Behaarung wie auf dem Metarostrum, Prorostrum robust, nach vorn auffällig verbreitert, Vorderrand flach, breit eingebuchtet, Seitenkanten im basalen Teil scharfkantig erhaben, sägezähnig, dann plötzlich abgebrochen und flach, Punktierung an der Basis fehlend, sonst warzig. Unterseite mit scharfem glattem Mittelkiel, die Seitenkanten grob punktiert und in den Punkten lang behaart. 2. Fühlerglied etwa quadratisch, 3. lang, kegelig, 4. und 5. von ähnlicher Gestalt aber kürzer, die folgenden walzig, 6.—8. quadratisch, 9 und 10 zylindrisch, 11. allmählich zugespitzt, so lang wie das 9. und 10 zusammen. Alle Glieder locker stehend, stark grubig punktiert, vom 4. ab mit rugoser Längsskulptur Prothorax eiförmig, nadelstichig punktiert und anliegend behaart, Prosternum unbehaart.—Elytren an der Basis gerade, nach dem Absturz zu allmähilch verschmälert, - Hinterecken stumpflich zugespitzt, nach der Innennaht dreieckig eingekerbt. Lage der Schmuckzeichnung: Abb. 10. Beine normal—Metasternum, 1. und 2. Abdominalsegment zart, zerstreut punktiert, 3 -5 Segment an den Seiten kräftig punktiert und zottig behaart.

♀ Prorostrum drehrund, Abdomen ungefurcht.

Länge (total): ♀ 17·0 mm. ♂ 17·5 mm. *Breite* (Prothorax): ♂ 3·0 mm. ♀ 3·0 mm.

Heimat: Perak. Sammler: Doherty. Aus Sammlung Fry.

Typen im British Museum.

Alle *Pseudorychodes*-Arten haben ein schmäleres Prorostrum, bei keiner findet sich eine so auffallende Zahnbildung an den Kanten des Prorostrums. Infolge dieser eigenartigen Bezahnung macht der ♂ einen abweichenden Eindruck. Trotzdem habe ich die neue Art bei der gattung belassen, weil alle sonstigen Eigenschaften durchaus mit der Gattunggsdiagnose übereinstimmen. Die *Pseudorychodes*-Arten sind ohnehin nicht einheitlich und der Gattungsbegriff ist nicht zu eng zu ziehen. Er muss so Allgemein bleiben, wie ich ihn in der Bestimmungstabelle meiner Arbeit (Arch. Nat. 86. 1920, 82 ff.) gegeben habe. Auf dem Prothorax findet sich übrigens die Andeutung einer Mittelfurche.

Suborychodes delectabilis n. sp.

♂ Einfarbig schwarz, Fühler und Beine schwarzbraun, Glanz mässig — Kopf ohne Mittelfurche, Seiten vor den Augen mit etwa 6 tiefen Punkten, die zum Teil auf dem Metarostrum stehen, Unterseite an den Augen mit mehreren tiefen Punkten, weitere Punktierung fehlt,—

Mittelfurche des Metarostrums tief, Unterseite mit mehreren groben Punkten neben der Mittellinie, Mesorostrum schmal gefurcht, Punktierung sehr gering.— Prothorax unpunktiert.— 1. und 2. Rippe auf den Elytren tief und schmal, 1. u. 2. Furche tief, die folgenden nur am Absturz und in der in Abbildung 11 gegebenen Weise angeordnet- Metasternum, 1. und 2. Abdominal segment kräftig gefurcht, 3. und 4. an den Seiten behaart, 5. an den Seiten eingedrückt, nur an der Basis behaart, Punktierung fast fehlend.

Länge (total): 13·0 mm. *Breite* (Prothorax): 2·0 mm.

Heimat: Es ist keine Patria angegeben, das Tier kann aber nur entweder aus Indien oder Assam stammen. Ich glaube aber mehr, dass Indien selbst in Frage kommt, denn die allgemeine tiefe Farbe ist in Assam nicht zu finden und das Stück fand sich auch mit anderm Material aus diesem Gebiet vor. [Probably ex Coll. T. R. Bell, Kanara. C.F.C.B.]

Typus in Forest Research Institute, Dehra Dun.

Die einzige verwandte Art ist in Malakka, Assam und Indien gefunden worden (*intermedius* Kln.) Von dieser trennt die schwarze Farbe, eine Seltenheit bei den Arrhenodini. Es kann sich um eine melanistische Form handeln, die Schmuckzeichnung ist nicht erkennbar. Die Differenzen gegen *intermedius* sind folgende: Kopf mehr rhombisch, Augen den Hinterrand nicht berührend, Metarostrum einfurchig, Seitenfurche fehlend, Seiten mit tiefen Punkten, Prorostrum schmaler, nach vorn weniger erweitert, Aussenecken nicht bedornt, Fühler mehr schlank, auf den Elytren neben der Sutura nur noch eine tiefe Rippe, während es bei *intermedius* zwei sind. Davon ist die 3. (2. neben der Sutura) sehr breit. Es ist die neue Art also bestimmt von *intermedius* sehr verschieden, die Gattung kann die Art aber mit einschliessen.

Parorychodes cereus n. sp.

♂ Dunkel, kastanienbraun bis violettbraun, Prorostrum mehr oder weniger, Vorderkanten der Fühlerglieder, Halsrand des Prothorax und Schenkel und Schienen an Basis und Knie schwärzlich, Glanz mässig.— Kopf ungefurcht, Hinterrand gerade, Punktierung einzeln, Unterseite mit warziger Skulptur, Augen gross, fast den ganzen seitlichen Kopf einnehmend.— Metarostrum kürzer als das Prorostrum, nach vorn verengt, breit, flach gefurcht, Skulptur auf Ober — und Unterseite wie beim Kopfe, vor den Augen mit undeutlichen Apophysen. Mesorostrum flach, wie das Metarostrum gefurcht. Prorostrum an der Basis scharfkantig, nach unten schräg erweitert, nach dem Vorderrande zu fast auf Kopfbreite erweitert, überall kräftig warzig skulptiert, Vorderrand tief eingebuchtet. Unterseite des Mesorostrums und des Prorostrums im basalen Teil gekielt, nach dem Vorderrand zu verflacht. Mandibeln einen kleinen freien Raum einschliessend.— Vom 2.—5. Fühlerglied

an Länge zunehmend, die folgenden, bis zum 10. einschliesslich etwa gleich lang, 11. langspitzig, 1.—5. kegelig, 6.—11. walzig, vom 4. ab mit dichter Unterbehaarung.— Prothorax fast ganz durchgehend gefurcht, Punktierung einzeln, zart, Seiten warzig skulptiert, Prosternum abgeplattet, mit ähnlicher Skulptur.—Auf den Elytren 4 deutliche Rippen, die nach den Seiten in grobe Punktstreifen übergehen, auf dem Absturz sind alle Rippen scharf ausgebildet. Schmuckzeichnung in gleicher Anlage wie bei *degener* Senna.— Vorder—und Mittelschenkel keulig, Hinterschenkel an der Basis auf der Oberkante bucklig verdickt, sehr breit und platt, fast rechteckig, Schenkeldorn klein, Unterkante einzeln behaart, Vorderschienen nicht gekrümmt, ungedornt, Tarsen normal.— Metasternum und Abdominalsegmente 1. und 2. kräftig längsgefurcht, Punktierung sehr zerstreut, 3. und 4. stärker, 5. sehr dicht und kräftig punktiert, an den Seiten und dem Hinterrand dicht behaart.

♀ Kopf gedrungen, Metarostrum sehr kurz, Prorostrum lang fadenförmig, Seitenskulptur des Prothorax fast fehlend, Hinterschenkel etwas schwächer ausgebildet,

Länge (total) : ♂ 20 mm. *Breite* (Prothorax) ♂ 3·0 mm.
♀ 17·5 mm. 3·0 mm.

Heimat : Nambor Res., Sibsagar, Assam. 29 IV. 1921. von C.F.C. Beeson gesammelt.

Cereus gehört in die Nähe von *degener* Senna, unterscheidet sich gut durch folgende Merkmale. Der Kopf ist am Hinterrand nicht eingekerbt sondern gerade, der Prothorax ist bestimmt punktiert; auf alle Fälle aber durch die stark erweiterten Hinterschenkel. Es dürfte sich um eine Vikariante des in Birmah und auf den Andamanen lebenden *degener* handeln.

CALORYCHODES n. g.

Schön, *Orychodes* gen. Brenth.

♂ Kopf quer, viel breiter als lang. hinten gerade, Oberseite platt, flach gefurcht, Unterseite platt, Gulargrube tief, dreieckig, Augen sehr grob, den ganzen seitlichen Kopf einnehmend, prominent, hinter den Augen nur ein ganz schmaler Kopfstreifen.— Metarostrum kurz, nur so lang wie der Kopf, Mittelfurche breit, in Nähe des Mesorostrums mit kielartig erhabenen, rundlichen Kanten, Apophysen vor den Augen klein, eine kleine unten und oben gelegene Brücke bildend, Mesorostrum mit halbrechteckigen Erweiterungen, Mittelfurche wie auf dem Metarostrum mit stark aufgebogenen Kanten, mitten auf dem Mesorostrum ein flacher niedriger Querbalken, Prorostrum viel länger als das Metarostrum, breit auf dem Mesorostrum ansitzend und erheblich nach vorn verbreitert

Seitenkanten im basalen Teil erhaben, breitkantig, in den Mitte breit unterbrochen, nach vorn zu fallen die Ränder ab. Vorderrand breit nach innen eingebuchtet, Unterseite vom Kopf anfangend vertieft, Meso —und Prorostrum stark ausgehöhlt, Vorderrand auf der Unterseite breit und tief nach hinten rechteckig ausgeschnitten. Mandibeln zart, aneinandergeschlagen, einen kleinen Raum einschliessend.— Fühler zart, vom 2. — 5. Glied an Länge zunehmend, vom 6.— 10. gleichlang, 11. so lang wie das 9. und 10. zusammen. 2. — 5. kegelig, die folgenden walzig, alle Glieder locker gestellt.— Prothorax breit elliptisch, in der basalen Hälfte abgeflacht, zart gefurcht, antecoxales Prosternum platt, postcoxales grubig runzelig. — Elytren robust, an der Basis fast gerade, Seiten parallel, am Hinterrand gleichmä ssig gerundet. 1.— 4. Rippe deutlich, die folgenden flach, 9. und 10. wieder deutlicher, am Absturz alle Rippen normal entwickelt, die oben liegenden Rippen von wechselnder Breite. 1.— 3. Furche unpunktiert, die folgenden durch flache Punktierung gekennzeichnet. Alle Rippen viel breiter als die Furchen, Schmuckzeichnung vorhanden.— Beine zart, Schenkel schlank, Keule mittelstark, Dorn klein, Schienen rundlich, gerade, auf der Mitte innenseits etwas verdickt. Tarsen schlank, Metatarsus länger als das 2. Glied, Klauenglied sehr lang. Metatarsus, 1. und 2. Abdominalsegment längsgefurcht, Quernaht zwischen dem 1. und 2. Segment an den Seiten tief, 3. und 4. Segment gleich lang, 5. abgeplattet.

Typus der Gattg : *C. decens* n. sp.

Es kann keinem Zweifel unterliegen, dass die neue Gattung zur *Orychodes* Verwandtschaft gehört. Das Prorostrum hat eine grosse Ah nlichkeit mit *Pseudorychodes damnosus* Die nächste Verwandtschaft ishdie Gattung *Suborychodes* Kln. Bei *Calorychodes* ist der Kopf breit, die Unterseite hat keine Punktierung, der Rüssel ist von ganz anderer Bauart, der Prothorax gefurcht, platt. Die Beine sind bei *Calorychodes* sehr schlank und der Metatarsus länger als das 2. Glied. Bei *Suborychodes* treffen die gegenteiligen Merkmale zu. Übereinstimmend ist der Bau der Elytren und die Art der Rippenausbildung, ferner ist bei beiden Gattungen Metasternum und Abdomen gefurcht. Damit ist die systematische Stellung festgelegt.

Calorychodes decens n. sp.

Hell kastanienbraun, Elytren dunkler, Schmuckzeichnung orange, am ganzen Körper hochglänzend. Kopf und die Kanten des Meta — und Mesorostrums einzeln nadelstichig punktiert. Prorostrum in der Vorderrandspartie und die Mandibeln warzig skulptiert ; Fühlerglieder vom 3. ab behaart, vom 4. mit tiefer Längsskulptur, vom 9. ab mit dichter Unterbehaarung.— Punktierung des Prothorax sehr zart, die

Mittelfurche bildet an der Basis eine dreieckige Einkerbung, ist sonst aber sehr zart und nimmt nach vorn an Deutlichkeit ab.— Lage der Schmuckzeichnung auf den Elytren: Rippe 3 je ein kurzes Streifchen basal, postmedian und apical, 4. desgl., median und postmedian, 5. desgl, postmedian 8. und 9. kurze, Posthumerale, letztere ausserdem noch kürzere Apicalstreifen.— Unterseite des Körpers sehr zart punktiert, nur das 3.—5. Abdominal segment an den Rändern mit dichter Punktierung.

♀ nicht gesehen.

Länge (total): 11- 15, 5 mm. *Breite* (Prothorax): 2·2—3·0 mm. circa. *Heimat*: Burma, Ruby Mines. Sammler: Doherty.

3 ♂♂ im British Museum.

BELOPHERINI.

Euphenges distributus n. sp.

♂ Mit *ceylonicus* Calabr. und *deliberatus* Kln. verwandt. Von beiden Arten durch die ganz abweichende Anlage der Schmuckzeichnung auf den Elytren leicht zu trennen. Letztere Art ist durch die ungedornten, gerundeten Elytren weiter entfernt und nur Auseinandersetzung mit *ceylonicus* nötig. Die trennenden Merkmale sind folgende: Der hohe Glanz fehlt, nur die Körperunterseite ist hochglänzend, der Prothorax ist nicht schwarzgestreift, sondern einfarbig carminrot.— Kopf deutlich, wenn auch nur flach gefurcht.— 1. und 2. Abdominalsegment kräftig längsgefurcht, 3.— 5. an den Seiten dicht behaart.— Lage der Schmuckzeichnung: 3. Rippe langer Basalstreifen, kürzerer postmedian, ganz kurz apical, 4. je ein Streifen median und postmedian, 5. basaler Punkt, Streifen postmedian, 6. postmedian, 8. und 9. lange Posthumerale, letztere ferner kürzerer Apicalstreifen.— Die Vorderbeine sind übrigens ebenfalls von abweichendem Bau. Die Schenkel tragen vor dem üblichen Dorn noch einen kleinen und die Schienen sind in der Mitte nach innen vorgewölbt.

Länge (total): 21·0 mm. *Breite* (Prothorax): 3·5 mm.

Heimat: Perak, Sammler: Doherty. Aus Coll. Fry.

Typus im British Museum.

Euphenges deliberatus n. sp.

♂ Habituell *Euphenges ceylonica* gleich, durch folgende Merkmale sicher zu trennen. Kopf breit aber flach gefurcht, Fühler vom 9. Gliede an mit dichter Unterbehaarung, desgleichen mit langer, zarter, abstehender Behaarung vom 3. Gliede ab, die bis zum 9. bleibt, dann schwä-

cher wird. Elytren an den hinteren Aussenecken nicht kurz gezahnt sondern gemeinsam rundlich abgestumpft. Der Prothorax ist zart aber bestimmt bis ins vordere Drittel gefurcht.

Länge (total): 24 mm. *Breite* (Prothorax): 4·0 mm.

Heimat: Kanara Bombay. Sammler T. R. Bell, VI, 1907.

Typus in der Sammlung der Forest Research Institute.

Es handelt sich um eine Vikariante der ceylonischen Art. Calabresi hat eine zweite Art von Penang beschrieben, die sich von *ceylonica* ziemlich weit entfernt. *Deliberatus* steht der ersteren weit näher und vermittelt den Ubergang der westlichen zur östlichen Art.

Heteroblysmia cava n. sp.

♀ Einfarbig violettbraun, Schmuckzeichnung der Elytren schmutzigorange, am ganzen Körper glänzend— In den wichtigsten Merkmalen mit *vittata* Calabr. übereinstimmend, aber durch die allgemeine Ausfärbung und die gänzlich andere Anlage der chmuckzeichnung verschieden. Die Körperfarbe ist allgemein viel dunkler und es fehlen alle schwarzen Zeichnungselemente,die bei *vittata* auf Rüssel und Prothorax ausgebildet sind. — Die Elytren sind bei *vit'ata* mit einer bestimmten Querbinde ausgezeichnet, basal, ante — und postmedian und apical. Bei *cava* sind diese Binden kaum noch erkennbar und durch eine, im Tribus höchstselt ne Anordnung der Schmuckzeichnung bemerkenswert.

Länge (total): 14·0 mm. *Breite* (Prothorax): 2·2 mm. circa.

Heimat: Penang.

Typus bezeichnet: Lamb. 93·60 im British Museum.

Die bisher bekannt n *Heteroblysmia*-Arten stammen sämtlich von Borneo. Es ha delt sich hier um eine sicher zur Gattung gehörige Art. Die Verb eitung erstreckt sich also recht weit nach Westen und es ist anzunehmen, dass sich eventuell auf Sumatra weitere Vertreter finden werden.

Die Elytrenzeichnung ist noch etwas unklar, die Binden treten nur unscharf hervor, weiteres Material muss Aufklärung bringen. Die *Heteroblysmia* — Arten scheinen noch alle in der Umbildung bezw. Consolidierung der Zeichnung begriffen zu s in. ♂ nicht gesehen.

TERATICORHYNCHUS n.g.

(Abenteuerlich und Rüssel).

♂ Kopf etwa quadratisch, vom Halse scharf abgesetzt, hintere Aussenecken scharf, Obersei e warzig skulptiert, auf den Warze behaart. Unterseite mit tiefer Gulargrube, Skulptur wie auf der Oberseite, nur die

Mittelfurche frei, Augen gross, im halben Augendurchmesser vom Hinterrand des Kopfes entfernt.— Metarostrum dreimal so lang wie der Kopf, gegen das Mesorostrum nur wenig verschmälert, rundlich, stark dornig und warzig skulptiert, in der Mitte eine schmale Rinne freilassend, Unterseite wie oberseits mit glatter Mittelfurche. Mesorostrum wenig erweitert, Mittelfurche wenig schmaler als auf dem Metarostrum, Skulptur wie dort, neben der Mitte jederseits ein stumpfer Dorn, nach der Unterseite steil abschüssig, Unterseite mit drei schmalen Kielen, ohne Dorn und Warzen. Prorostrum länger als das Metarostrum, oberhalb mit zwei Paar aufrechtstehenden Zähnen besetzt, unter dem vorderen Paar je ein seitlicher grosser, nach oben gebogener Zahn, am Absturz gleiche Zähne von grösserer Dimension, Vorderrand gerade, Skulptur gering, Unterseite mit breiter Mittelfurche, Skulptur wie oberseits.— Fühler lang, zart. 1. Glied an der Basis von oben gegen unten stark komprimiert, die allgemeine Gestalt unförmig, mehr oder weniger rechteckig, sehr gross, 2. und 3. Glied einzeln, nicht kürzer als das erste, die folgenden Glieder nach vorn zu an Grösse abnehmend, 11. kürzer als das 9. und 10. zusammen. Bis zum 4. an der Spitze nodos, dann walzig, vom 4. ab mit zunehmender dichter Behaarung, Unterkante vom 3. Glie 'e ab mit langen, zottigen Haaren. Prothorax eiförmig, am Halse stark verengt, grösste Breite über den Hüften, mit Ausnahme einer im basalen Teil vorhandenen flachen Mitt lfurche grob unzelig-warzig skulptiert, in den Punkten mit dichten, kleinen Haarbüscheln. Prosteıum vor den Hüften gefurcht. -Elytren an der Ba is gerade, nach hinten zu allmählich verschmälert, Hinterecken stumpfspitzig, gerippt gefurcht, Furchen grob gegittert.— Vorderbeine verlängert. Schenkel schmächtig, Stiel lang, Keule zart, gedornt, Schienen gerade, an der Basis etwas zusammengedrückt, Vorderrand an den Tarsen mit grossem Seitendorn. Tarsen gross, 1. länger als das 2, Sohlen dicht filzig. Klauenglied gross, keulig.---Metarostrum an der Basis tief grubig, neben der Grube jenseits eine zapfenartige Vorstülpung. 1. und 2. Abdominalsegment breit, flach gefurcht, 1. an der Basis tiefer. Quernaht zwischen den Segmenten an den Seiten tief.

Typus der Gattung : *T. defectus* n. sp.

Die neue Gattung gehört in eine Gruppe zu der *Apocemus* Calabr., *Megateras* Kln , *Allacompsus* Kln. und *Heterorhynchus* Calabr. gehören. Es sind alles grosse Arten mit nicht vergrösserten Vorderbeinen und einen in der verschiedensten Weise bewehrten Rüssel. Keine der bekann ten Gattungen hat ein bewehrtes Prorostrum, schon dadurch unterscheidet sich *Teraticorhynchus* von allen anderen und scheint auf den ersten Blick gar nicht zu den Belopherini, sondern zu *Stratiorrhina* zu gehören. Was von den bekannten Gattungen weiter trennt, sind die

auffallend stark behaarten Fühler, die ichsonst noch nicht gesehen habe. Ganz abweichender Bauart ist ferner das basale Fühler-glied, das an seiner Basis auf etwa $\frac{1}{5}$ seines Durchmessers zusammengepresst ist. Es scheint fast, dass dieser Verwandtschaftskreis sich noch erheblich erweitern wird, es dürften aber alles nur kleine Gattungen bleiben.

T. defectus n. sp.

Dunkelviolettbraun, Halsring und die Schenkel an Basis und Knie schwärzlich, Glanz mittelmässig, durch die starke Skulptur verdeckt Rippen auf den Elytren mit einzelnen Punkten weitläufig besetzt, in den Punkten mit Haaren besetzt. Die Form der Haare ist reihenweise verschieden, entweder lang, fadenförmig oder kurz, keulig. Die Schmuckzeichnung ist nicht sicher festzustellen, weil die Gitterung zu stark ist, lässt sich aber in einer basalen, ante,-postmedianen und apicalen Binde erkennen. Prorostrum mit flachen Haarbüscheln in den Punkten., Metasternum in den Mittelpartien lang, an den Seiten blattartig behaart Abdomen an den Seiten desgleichen. Hüften und Schenkel anliegend blattartig behaart. Schienen innenseits zottig, rostrot, sehr dicth behaart.

Länge (total): 36 mm. *Breite* (Prothorax): 6, 0 mm.

Heimat: Tenasserim. Aus Coll. Fry.

Typus im British Museum.

Pseudobelopherus deductus n. sp.

♂ Violettbraun, Halsring, Vorderkanten der Fühlerglieder und Schenkel an Basis und Knie in sehr geringem Umfange schwarz, Oberseite des Körpers ganz matt, Unterseite und die Beine schwach glänzend.—Die warzigen Tuberkeln auf Seiten und Unterseite des Metarostrums stark. Elytren am Absturz sehr stark verschmälert, Dornen spitz und horizontal abstehend, nach innen gerichtet, Schmuckzeichnung durch die grobe Gitterung nicht sicher festzustellen. Metasternum vor dem Abdomem grubig vertieft, 1. und 2. Abdominalsegment schmal aber scharf gefurcht, Quernaht zwischen den Segmenten an den Seiten deutlich.

Länge (total): 18·0 mm. *Breite* (Prothorax): 3·0 mm.

Heimat: Perak. Sammler: Doherty. Aus Coll. Fry.

Typus im British Museum.

Aus der Gattung *Pseudobelopherus* ist bisher nur *orientalis* Calabr. bekannt. Die Gattungsdiagnose wird nur insofern beeinträchtigt als bei den Elytren die Bezeichnung: "apice valde attenuata, singulatim breviter acute mucronata" nicht zutrifft. Die Dorne von *deductus*

sind länger, stellen einen tatsächlich spitzen Dorn dar, während *orientalis* nur nach aussen gerichtete Ecken hat. *Orientalis* ist eine helle, rotbraune Art, mit ungefurchtem Metasternum und einem Abdomen, das nur an der Basis zart gefurcht ist, bei *deductus* ist die Furchung sehr kräftig, durchgehend vorhanden. Die Schmuckzeichnung auf den Elytren ist ganz verschieden. Ich kann die Differenzen aber nicht genau angeben, weil die rugose Gitterung zu stark ist.

Ectocemus contractus n. sp.

♂ Schokoladenbraun, Schmuckzeichnung orange, mässig, etwas fettig glänzend.-- Kopf seitlich und über den Augen runzelig, sonst einzeln warzig, gewölbt, Unterseite mit Mittelkiel, grob warzig skulptiert. Metarostrum gefurcht, Kanten der Furche eine stumpfdornige Leiste bildend, Skulptur an den Seiten tiefe Punkte bildend, von welchen tiefe Rinnen strahlenförmig auslaufen, Unterseite desgleichen, Mesorostrum schwach erweitert, wie das Metarostrum gefurcht, platt, Prorostrum mit geringer Einschnürung oberseits, unterseits dagegen scharf abgesetzt, Skulptur gering. 3. Fühlerglied kürzer als das 2., die folgenden fast gleichlang, 2. mehr walzig, 3.--5. kegelig, die folgenden walzig, 11. so lang wie das 9. und 10. zusammen, vom 1. ab behaart und tief skulptiert. - Prothorax im basalen Teil dicht, zum Teil kräftig punktiert, nach dem Halse zu lässt die Punktierung nach, fein chagriniert und dicht behaart. - Elytren lang behaart, Lage der Schmuckzeichnung: Rippe 3 lang basal, kurz postmedian und apical, 4 median und postmedian, 5 basal, ante -und postmedian, 6 ante--und postmedian, 7 desgleichen, 8 basal und posthumeral, 9 posthumeral und apical.— Schenkel und Schienen auf der Unterkante behaart, Hüften, namentlich die vorderen desgleichen. Metasternum, 1. und 2. Abdominalsegment gefurcht, Skulptur aus tiefen, behaarten Punkten bestehend, 3. und 4. zottig behaart, 5. zerstreut punktiert und nur gering, an den Seiten behaart.

Länge (total): 16·5 mm. *Breite* (Prothorax): 2·2 mm.

Heimat: Cambodia.

Typus im British Museum

Von allen anderen Arten durch die geringe Einschnürung des Prorostrums und durch die auffalende, allgemeine Behaarung, die sonst keine Art hat, gekennzeichnet. Vielleicht wäre es richtiger, die neue Art in eine eigene Gattung zu bringen, es ist aber doch besser abzuwarten, ob nicht noch weitere Arten zu finden sind, die den Übergang vermitteln. Auf der Rüsselunterseite ist gegen die anderen Arten kein Unterschied zu finden.

Anepsiotes bellus n. sp.

♀ Einfarbig violettbraun, Fühler etwas heller, Schmuckzeichnung auf den Elytren dunkel-blutrot, am ganzen Körper glänzend, oberseits schwächer, unterseits stärker.— Hinterhaupt zart gefurcht, Furche zwischen den Augen unterbrochen, die ganze Oberseite einzeln, warzig skulptiert. Augen in ½ Augendurchmesser vom Halsrand entfernt, dieser Teil ohne Skulptur. . Unterseite mit dreieckiger Gulargrube, am Metarostrum mit grobem Punkt beiderseits der Mitte, unter den Augen einige Warzenpunkte.—Metarostrum gefurcht und wie der Kopf skulptiert, Seiten mit grubigen Vertiefungen, auf der Unterseite dieselben groben Punkte und warzigen Erhöhungen wie auf dem Kopfe; Mesorostrum erhöht, schmal gefurcht; Prorostrum ohne Skulptur.- Fühler wie beim Typus (*Schenklingi* Kleine). Prothorax im wesentlichen dem Typus gleich, aber am Hinterrand kräftig punktiert und an den Seiten zottig, dicht behaart. Vorderhüften stark punktiert, Hüftringe zottig, dicht behaart.— Elytren wie beim Typus.- Schenkel und Schienen unterseits mit dichter, filziger Behaarung, Tarsen desgleichen.- Das 3. und 4. Abdominalsegment dicht, zottig behaart 5. nur an den Seiten mit gleichem Haarbesatz.

Länge (total): 23 mm. *Breite* (Prothorax): 3·5 mm.

Heimat: British India, Katgal, 23. XI. 97.

Die neue Art ist nur mit *Schenklingi* Kleine verwandt Von *Kleinei* Calabr. und *elegans* Calabr. trennen die überall gitterfurchigen Rippen, von *luzonicus* Calabr. der nicht quere Kopf, von *nitidicollis* Calabr. der matte Prothorax. Von allen bekannten Arten trennt die grubige Skulptur an den Seiten und auf der Unterseite des Metarostrums.

Anepsiotes commendabilis n. sp.

♂ Einfarbig schokoladenbraun, Schmuckzeichnung schmutziggelb, vordere Extremitäten matt, Elytren, Metasternum, Abdomen und Beine glänzend.— Kopf ungefurcht, gewölbt, chagriniert und grob punktiert, Seiten desgleichen, Unterseite dicht warzig skulptiert.— Metarostrum gefurcht, Skulptur ober — und unterseits wie auf dem Kopfe, Mesorostrum schwach verbreitert, seitlich stumpfspitzig, ungefurcht, etwas gewölbt, Prorostrum in üblicher Weise gezahnt, warzig skulptiert, Unterseite des Mesorostrums schwach warzig, des Prorostrums stark glänzend.— Fühler auf allen Gliedern grob und dicht punktiert.-- Prothorax mit undeutlicher Mittelfurche, dicht chagriniert, im basalen Teil grob punktiert und in den Punkten behaart, nach vorn zu lässt die Punktierung nach. Prosternum glatt, vor den Hüften kurz behaart.— Elytren

kräftig gitterfurchig, auf den Rippen kurz anliegend behaart. Lage der Schmuckzeichnung : Rippe 2 kurzer Apicalstreifen, 3 langer basal, kurzer postmedian und apical, 4 kurzer ante — und postmedian, 5 je ein kleiner Fleck basal und im vordern Drittel, ein längeres Streifchen postmedian, 6 postmedian, 8 posthumeral, 9 desgl. und apical. - Beine ohne besondere Merkmale.— Metasternum an der Basis grubig eingedrückt, 1. und 2. Abdominalsegment gefurcht, einzeln kräftig punktiert und lang behaart, 3.— 5. Segment kräftig punktiert und kurz behaart, an den Rändern dicht behaart, filzig.

Länge (total) : 15 mm. *Breite* (Prothorax) : 3 mm.

Heimat : S. India : Travancore Tea Co. Von G. S. Imray gesammelt. Typus im British Museum.

Die Art ist durch die eigenartige Skulptur mit keiner anderen zu verwechseln. Alle anderen Arten sind glatt und unbehaart.

ITHYSTENINI.

PLESIOPHOCYLIDES n. gen.

(Nebenan und Phocylides gen. Brenth.)

♂ Kopf länger als breit, nicht kegelig sondern nach vorn mässig verschmälert, am Halse fest ansitzend, nicht getrennt, Oberseite platt, nicht gefurcht, zwischen den Augen mit tiefer, breiter Grube, Unterseite mit rinnenförmiger, plötzlich stark erweiterter Gulargrube, unter den Augen je eine tiefe, grob punktierte, stark borstig, langbehaarte Rinne, die sich auf das Metarostrum fortsetzt und nur einen schmalen Mittelkiel frei lässt. Augen gross, nach vorn stehend, in weniger als Augendurchmesser vom Hinterrand des Kopfes entfernt.- Rüssel lang, Metarostrum länger als das Prorostrum, oberseits abgeflacht, Kanten unscharf, gegen das Mesorostrum seitlich etwas erweitert, Mesorostrum flach verbreitert, in der Mitte flach gefurcht, gegen das Prorostrum erweitert sich die Furche, Prorostrum kantig, nach dem Vorderrande nicht erweitert und an den Kanten rundlicher, an der Basis gefurcht, sonst glatt, Vorderand eingebuchtet, Mandibeln klein, Unterseite des Meso — und Prorostrums gekielt aber nicht punktiert und behaart.- Fühler kurz, 1. Glied gross, 2. sehr kurz, 3. 8. nach vorn an Länge abnehmend, 3. 5. kegelig, 6.- -8. mehr tonnenförmig, 9. und 10. erheblich länger, jedes so lang wie das 7. und 8. zusammen, 11. schlank, zugespitzt, so lang wie das 9. und 10. zusammen, alle Glieder locker stehend, 3.—8. einzeln behaart, 9. -11. mit dichter Unterbehaarung.— Prothorax elliptisch, tiefgefurcht, Prosternum flach gewölbt.— Elytren an der Basis flach abgeschrägt, Humerus gerundet, Seiten parallel, hinten mit breiten Anhängen, neben der Sutura keine tiefgetrennte Rippe, nur die

Suturalfurche tief, alle anderen Rippen flach, Furchen mit grosser, flacher Gitterung.— Beine kurz, Schenkel kräftig keulig, ungedornt, Schienen gerade, schlank, nicht stielrund sondern mehr kantig, Metatarsus so lang wie das 2. und 3. Glied zusammen (Hinterbeine) oder fast so lang (Vorder — und Mittelbeine).- Metasternum zart gefurcht. 1. Abdominalsegment flach, kurz eingedrückt, 2. gewölbt, 3. und 4. fast gleich gross.

Typus der Gattung : *Pl. conditus* n. sp.

Die Unterbringung der Gattung stösst auf nicht unbedeutende Schwierigkeiten. Dem Habitus nach kann sie nur zu den Ithystenini und zwar in die Nähe von *Phocylides* kommen. Ganz abweichend ist die Gestalt des Kopfes, die stark an die Nemocephalini erinnert. Endlich sind auch Anklänge an die Pseudoceocephalini vorhanden. Ich halte es aber für das Beste, die Gattung bei den Ithystenini zu belassen und zwar mit *Phocylides* und *Pseudophocylides* in einem Verwandtschaftskreis. Das Vorstossen des Tribus nach Westen ist an sich nichts Ungewöhnliches, da auf den Andamanen gleichfalls Vertreter gefunden worden sind. So weit nach Norden wie die neue Gattung ist aber noch keine vorgedrungen.

Plesiophocylides conditius n. sp.

Schwärzlich mit einem Schein ins metallischgrüne oder broncebraun, mit Ausnahme der stark glänzenden Unterseite matt. Kopf tief nadelstichig punktiert, in den Augen kurz, anliegend, kräftig behaart, Seiten hinter den Augen glatter. Metarostrum oberseits mit ähnlicher Skulptur, an den Seiten rugos grubig punktiert und behaart, Mesorostrum glatter, Prorostrum an der Basis einzeln punktiert, nach vorn zu warzig, am Vorderrand selbst glatt. Seiten fast glatt. Prothorax dicht, grob rugos punktiert und kurz behaart, nach dem Halse zu nimmt die Punktierung an Feinheit und Dichte zu und die Behaarung wird schwächer.— Elytren dicht chagriniert, nadelstichig punktiert und kurz beborstet.— Metasternum und die beiden ersten Abdominalsegmente zerstreut punktiert, an den Seiten stärker, eben so am Hinterrande des 2. Segmentes, 3. und 4. mit je einer groben Punktreihe, 5. an der Basis grob und tief punktiert, nach der Spitze geht die Punktierung in eine tiefe Runzelung über.

Länge (total) : 33·0 mm. *Breite* (Prothorax) : 3·5 mm.
Heimat : India, Sylhet. Aus Sammlung Bowring.
Typus im British Museum.

Diurus compendiarius n. sp.

Ausserst schlanke Art, mit sehr langen Fühlern.— Kopf schlank, am Hinterrande eingekerbt, Oberseite, wenigstens bis zu den Augen, schwach gefurcht, dünn beschuppt, Augen in mehr als Augendurchmesser vom Hinterrand entfernt, unter dem Auge eine tiefe Rinne.— Metarostrum schlank, walzig, schwach in der Mitte gekielt, Mesorostrum stark verdickt, kräftig gefurcht, Prorostrum kurz, walzig.— Fühler fast bis an den Hinterrand der Elytren reichend, äusserst zart und schlank. 1. Glied keulig, 2. kürzer als das 1., zylindrisch, an der Spitze nodos verdickt, 3. etwa dreimal so lang als das 2., 3.— 6. gleich lang, 7. und 8. einzeln etwa ¾ so lang wie das Einzelglied von 3—6, 9.— 11. sehr kurz, zusammen etwas länger als das 8. allein, vom 2.– 8. sind die Glieder an der Spitze schwach nodos, 9.- -11. walzig, fein behaart. Prothorax deutlich gefurcht, Beschuppung nur neben der Mitte und über den Hüften. – Elytren plattgedrückt, nicht gewölbt, sehr schwach, aber nach ganz bestimmter Anordnung beschuppt, an der 4. Rippe rechtwinklig, scharfkantig. Anhänge kurz, aber nicht dornenförmig, behaart, sich nicht berührend. Beine ohne besondere Merkmale.

Länge (total) : 26 32 mm. *Breite* (Prothorax) : 1¾—2½ mm.

Länge der Fühler : 21 28 mm.

Heimat : India.

Typus bezeichnet Bowring 63. 47. Perak. 2 ♂♂ im British Museum, ♀ nicht gesehen.

Die Art ist mit *Spötteli* Kln. verwandt. Unterschied : Die Glieder nehmen vom 3. ab nicht an Länge ab, sondern das 3.-- 6. ist gleichlang, während das 7. und 8. erheblich kürzer ist, diese Glieder sind aber unter sich gleich lang. Das 9. bis 11. ist nicht so lang wie das 8. sondern erheblich kürzer. *Spötteli* ist von Java, sicher handelt es sich um eine Vicariante.

PSEUDOCEOCEPHALINI.

METATRACHELUS gen. nov.

Im Habitus *Schizotrachelus* ähnlich Kopf etwas länger als breit, am Hinterrand kaum eingekerbt, Oberseite flach gewölbt, zwischen den Augen tief grubig gefurcht, Seiten hinter den Augen grubig vertieft, Hinterrand aber vorhanden, Unterseite mit je einer Reihe grober Punkte unter den Augen oder filziger Mittelfurche. Augen gross, wenig prominent, nach vorn gerückt, in halbem Augendurchmesser vom Hinterrand entfernt.- – Metarostrum so lang wie das Prorostrum, walzig, nach vorn kaum verschmälert, walzig gerundet, Mesorostrum erweitert, platt,

undeutlich schmal gefurcht, Prorostrum an der Basis schmal, kantig, nach vorn allmählich erweitert, mit rundlichen Kanten, Vorderrand eingebogen, Mandibeln klein. Auf der Unterseite ein im vorderen Teil des Metarostrums beginnender, sich über das Meso — zum Prorostrum hinziehender breiter Mittelkiel.— Fühler gedrungen, kaum über den Halsrand reichend, 2.—8. Glied quer, 3. schwach kegelig, die folgenden scharfkantig, die vorderen etwas kegelig, 9. und 10. etwa quadratisch, 11. konisch, kräftig, so lang wie das 9. und 10. zusammen, alle Glieder locker stehend.— Prothorax schlank, eiförmig - elliptisch, Mittelfurche tief, durchgehend.— Elytren gegen den Absturz schmaler werdend, etwas verlängert und gemeinsam spitz auslaufend, ausser der Sutura keine Rippe vorhanden, Suturalfurche tief und breit, alle andern Rippen vollständig obsolet, die Furchen durch weitstehende, sehr zarte Punktierung kenntlich.— Beine schlank, Schenkel sehr dünn, Keule schmächtig, unbehaart, Behaarung am Stiel gering, Schienen im Verhältnis zum Schenkel kurz, schmächtig, gerade, innenseits etwas vorgebogen und dicht struppig behaart, alle Tarsen kurz, quer, Klauenglieder äusserst robust, klobig, walzig.— Metasternum nur an der Basis gefurcht 1. Abdominalsegment breit und flach eingedrückt, 2. weniger, Quernaht deutlich, Apicalsegment im Spitzenteil mit einer narbigskulptierten, kurz behaarten Platte.

Typus der Gattung: *M. comparativus* n. sp.

Metatrachelus comparativus n. sp.

Pechbraun, einfarbig, glänzend. Punktierung auf Kopf und Rüssel sehr zerstreut und zart. Prothorax mit gleicher Skulptur, nur im basalen Teil sind die Punkte etwas grösser. Unterseite des Körpers von gleicher Beschaffenheit.

Länge (total): 18·0 mm. *Breite* (Prothorax): 2·0 mm.

Heimat: Penang. Aus Sammlung Pascoe im British Museum.

Die Ähnlichkeit mit *Schizotrachelus* ist recht bedeutend, dennoch ist die Abtrennung sehr leicht, weil die Elytren mit Ausnahme der Sutura ohne jede Rippenbildung sind. Ich stelle die Gattung in die Nähe von *Schizotrachelus.*

FIGURENVERZEICHNIS.

DESCRIPTION OF PLATE I.

NEW SPECIES OF BRENTHIDAE.

Fig. 1. Middle joint of antenna of *Cyphagogus concavus.*

" 2. 3rd-5th antennal joints (below) and 6th-8th antennal joints (above) of *Cyphagogus confertulus.*

" 3. Middle joint of antenna of *Cyphagogus confidens.*

" 4. Head and basal joint of antenna of ♂ and ♀ of *Allaeometrus deformis.*

" 5. Base of elytra with the expanded humerus of *Trachelizus dividuus.*

" 6. Right halves of the meta and prorostrum of *Leptamorphocephalus cupidus.*

" 7. Head, from side, of *Hypomiolispa colorata.*

" 8. Head and rostrum of *Hemisamblus contemptus.*

" 9. Rostrum in outline of *Pseudorychodes damnosus.*

" 10. Arrangement of markings on elytra of *Pseudorychodes damnosus.*

" 11. Formation of ridges on the sides of the elytra of *Suborychodes delectabilis..*

" 12. Femur of *Parorychodes cereus.*

" 13. Apex of elytra of *Pseudobelopherus deductus.*

" 14. Rostrum from side of *Calorychodes decens.*

" 15. Head and rostrum from above of *Calorychodes decens.*

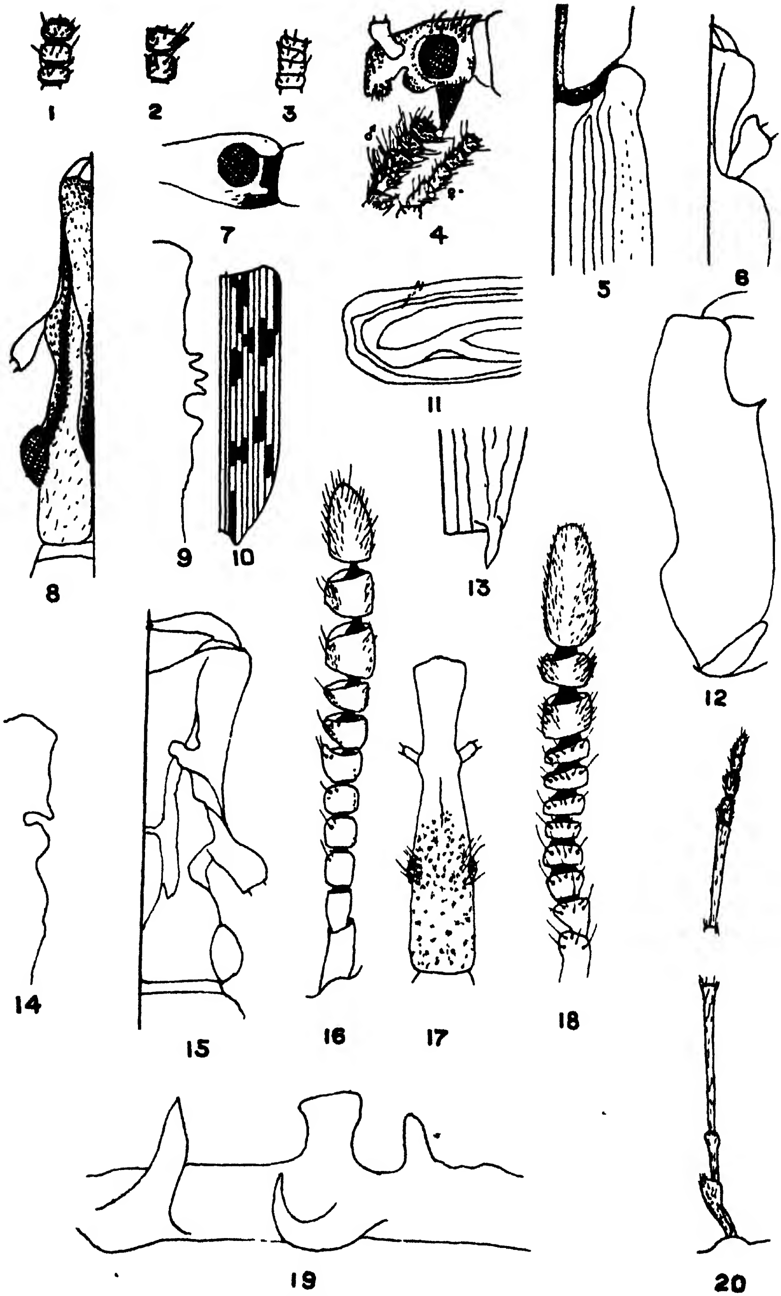
" 16. Antenna of *Cyphagogus fragosus.*

" 17. Head " " "

" 18. Antenna of *Parasambius fraudulentus.*

" 19. Rostrum from side of *Teraticorhynchus deductus.*

" 20. Antenna of *Diurus compendarius.*



NEW SPECIES OF BRENTHIDÆ.

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DESCRIPTION OF PLATE II.

NEW SPECIES OF BRENTHIDAE.

Fig. 21. Paramere of *Hypomiolispa conjugalis.*
,, 22. Penis ,, ,, ,,
,, 23. Paramere of *Hypomiolispa cruda.*
,, 24. Prorostrum of *Leptamorphocephalus cuneatus.*
,, 25. Rostrum of *Teraticorhynchus deductus.*
,, 26. Paramere of *Hemiorychodes curvus.*
,, 27. Head and base of rostrum of *Perorychodes arrowi.*
,, 28. Arrangement of markings on elytra of *Perorychodes arrowi.*
,, 29. ,, ,, ,, *Hemiorychodes dissonus.*
,, 30. ,, ,, ,, *Hemiorychodes curvus.*
,, 31. ,, ,, ,, *Hypomiolispa conjuncta.*
,, 32. ,, ,, ,, *Euphenges distributus.*
,, 33. ,, ,, ,, *Anepsiotes commendatu,*
,, 34. ,, ,, ,, *Heteroblysmia cava.*
,, 35. ,, ,, ,, *Hemiorychodes continens*


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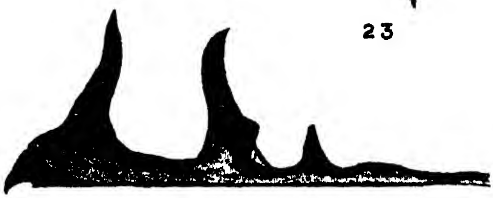
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NEW SPECIES OF BRENTHIDÆ.

A SYNOPTIC KEY TO THE GENERA OF THE BRENTHIDAE OF THE INDIAN REGION.

The following key to the subfamilies and genera of the Brenthidae recorded from British India and the neighbouring region has been prepared by Herr Kleine :—

KEY TO THE SUBFAMILIES.

1. Prothorax in front more or less compressed, generally hollowed out to receive the front legs ; if not, the elytra are pointed at the apex	*Calodrominae.*	
Prothorax in front not compressed, elytra not pointed .		2.
2. Inner side of the front tibiae heavily spined . . .	*Stereoderminae.*	
Not spined		3.
3. Small species, rarely exceeding 10 mm. ; femora with few exceptions not armed		4.
Large or very large species ; femora with few exceptions armed		5.
4. Head and antennae never deformed, of normal shape ; antennae generally ending in clubs	*Trachelizinae.*	
Head and rostrum more or less deformed, usually strongly so ; terminal joints not thickened	*Amorphocephalinae.*	
5. Antennae inserted in the middle of the rostrum, pro- and meta-rostrum of about equal length		6.
Antennae placed well in front, prorostrum much shorter than the metarostrum		8.
6. Elytra with ornate markings, following the course of the ribs ; prothorax not furrowed		7.
Elytra with ornate markings, independent of the course of the ribs ; prothorax deeply furrowed	*Pseudoceocephalinae.*	
7. Antennae short, mandibles generally large, projecting, sides of the elytra parallel, not narrowed towards the apex ; legs short ; general shape short and thick . .	*Arrhenodinae.*	
Antennae long ; mandibles, with few exceptions, small, not projecting ; elytra narrower towards the apex ; legs long ; general shape slender	*Belopherinae.*	
8. General shape very slender, narrow, with or without pubescent scales on the body	*Ithysteninae.*	

KEY TO THE GENERA.

CALODROMINAE.

1. Metatarsus of the hind legs as long as the whole insect .	*Calodromus* Guer.	
Metatarsus at most as long as the 2nd and 3rd joints together		2

2. Hind tibiae hypermorphous or of unusual shape, never normal	*Cyphagogus* Parry.
Hind tibiae normal	3.
3. Antennae placed in front, inserted in large sockets which are separated by a more or less narrow wall . .	4
Antennae always placed laterally, in the width of the rostrum	5.
4. Underside of the metarostrum half elliptical, with sharp edges, indented	*Spharganophasma* Kln.
Underside straight, not indented	*Callipareius* Senna.
5. Prothorax in front not at all or only slightly constricted	6.
Prothorax in front always constricted to receive the legs	8.
6. Underside of the head or of the rostrum without tooth or humpy thickening of the lateral edge. . . .	*Opisthenoxys* Kln.
Underside with a tooth, more or less large, or with a hump	7.
7. Body covered with scale-like, broad hairs . . .	*Pseudocyphagogus* Desbr.
Body without scale-like hairs	*Mesoderes* Senna.
8. Prothorax furrowed throughout	*Autometrus* Kln.
Prothorax furrowed only at its base	9.
9. Head below with teeth	10.
Head without teeth	12.
10. Ribs of the elytra not shortened	*Eterozemus* Senna.
Ribs shortened	11.
11. 1st and 3rd rib shortened at the base, enclosed by the 2nd and 4th	*Dictyotpterus* Kln.
2nd rib shortened, 3rd broader and higher than the others	*Allaeometrus* Senna.
12. 2nd rib narrower at its base	*Paraclidorrhinus* Senna
Suture and 2nd rib broad, all others narrow . . .	*Eusebus* Kln.

STEREODERMINAE.

Antennae long and thin, sometimes of the length of the body	*Jonthocerus* Lacord.
Antennae short and stout	*Cerobates* Schoenh.

TRACHELZINAE.

1. Elytra without strongly raised ribs, hinder edge straight	2.
Ribs partly strongly raised, hinder edge prolonged or toothed	14.
2. Prothorax not furrowed	*Anocamara* Kln.
Prothorax furrowed	3.

3.	Front tibiae in their middle at the inner side with a pointed wedge-like, hairy enlargement	4.
	Front tibiae not enlarged	5.
4.	Head at its hinder edge straight, above not broadly furrowed, prothorax normal, middle furrow delicate .	*Metatrachelizus* Kln.
	Head at its hinder margin with a square incision, above broadly furrowed, prothorax at the neck broadly widened, almost rectangular, towards the centre strongly inclined, middle furrow large, deep . .	*Aneorhachis* Kln.
5.	Besides the suture, one or two additional ribs are present lateral ribs at most indicated by punctation . .	6.
	All ribs are present	7.
6.	Head broad, eyes close to the posterior margin . .	*Trachelizus* Schoenh.
	Head longer than broad, eyes distant by their diameter from the neck	*Hemisamblus* Kln.
7.	Head above and at the sides with several indentations or incisions, or at its upper outer edge or laterally with a tubercle—like swelling	8.
	Head not indented, smoothly rounded off . . .	12.
8.	Front femora toothed	*Higonius* Lewis.
	Front femora not toothed	9.
9.	Head longer than broad, eyes much moved forwards	*Miolispa* Pasc.
	Head short, eyes always placed more or less closely to the base	
10.	Rib distinctly curved at the apex and forming a strong keel or hump	*Tulotus* Senna.
	Rib not specially marked	11.
11.	Head somewhat square, above on either side hump-like swollen, prorostrum round, furrowed almost up to the tip, highly shining species	*Miolispoides* Senna.
	Head transverse or triangular, above not swollen, prorostrum furrowed at most at the base or not at all, more or less 4-cornered species, only slightly shining . .	*Hypomiolispa* Kln.
12.	Prorostrum much longer than the metarostrum . .	*Araiorrhinus* Senna.
	Prorostrum only slightly longer than the metarostrum or of equal length	13.
13.	Metarostrum wedge-like, narrowed towards the mesorostrum	*Microtrachelizus* Senna.
14.	Suture at the posterior edge prolonged beyond the elytra	*Hoplopisthius* Senna.
	Suture not prolonged	*Carcinopisthius* Kolbe.

AMORPHOCEPHALINAE.

1.	Head rounded, at the utmost furrowed, head deformed .	2.
	Head and rostrum deformed	3.
2.	Head connected with the rostrum by a narrow longitudinal keel	*Symmorphocerus* Schoenh,
	Head and rostrum separate	*Cordus* Schoenh.
3.	Antennae laterally strongly compressed, several times broader than thick.	*Pausobrenthus* Gestro,
	Antennae cylindrical, normal	4.

4. Prorostrum narrower than the metarostrum . . . *Leptamorphocephalus* Kln.
 Prorostrum broader than the metarostrum . . . 5.
5. Pro- and mesorostrum below more or less drawn out in front and thickened, antennae nodose, elytra without ribs and furrows . . . . *Paramorphocephalus*, Kln.
 Pro- and mesorostrum below not thickened or protracted, antennae cylindrical, elytra ribbed furrowed . . *Amorphocephalus* Schoenh.

ARRHENODINAE.

1. Rostrum as broad as the head, or scarcely narrower, large, stout; mandibles always robust, enclosing a free space or not . . . . 2.
 Rostrum narrower than the head, broadened towards the anterior edge, with large, projecting mandibles which enclose a large, free space. . . . . . . *Eupsalis* Lacord.
 Rostrum of similar shape, mandibles small . . . 5.
 Rostrum at its front edge not broadened, parallel, mandibles very small . . . . *Corporaalia* Kln.
2. Prorostrum very broad, more or less parallel, front edge deeply incised, the mandibles hidden in the incision . . . . *Agriorrhynchus* Pow.
 Prorostrum always broadened towards the front edge, mostly only slightly. Mandibles not hidden in the incision of the front edge, but projecting . . . 3.
3. Rostrum thick, cylindrical very long as compared with the head . . . . *Eupeithes* Senna.
 Rostrum not cylindrical, of normal length . . . 4.
4. Mandibles large, pincer-like, enclosing a free space; head generally very long, eyes small, placed in front . . *Prophthalmus* Lacord.
 Mandibles not large, enclosing only a small free space; is the space large, then the mandibles are uniformly curved from their base to the apex . . . . *Baryrrhynchus* Lacord.
5. Prorostrum with laterally projecting teeth . . . *Stratiorrhina* Pasc.
 Not toothed . . . . 6.
6. Front tibiae strongly curved, on their distal third with a stout internal tooth . . . . 7.
 Front tibiae more or less straight, on their distal third not toothed, at most with a slight thickening . . 8.
7. Head behind the eyes with lateral spines, or produced posteriorly above the neck . . . . . . *Caenorychodes* Kln.
 Head without spines and not produced over the neck . . . . *Perorychodes* Kln.
8. Elytra with lattice-like furrows . . . . . . 9.
 Without lattice-like furrows . . . . . . 11.
9. 1st and 2nd abdominal segments not furrowed . . *Hemiorychodes* Kln
 1st and 2nd abdominal segments furrowed . . . 10.
10. Dull, slender forms . . . . *Syorymchodes* Kln.
 Highly shining, stout forms. . . . . . *Pseudorychodes* Senna.
11. 1st and 2nd abdominal segments not furrowed . . *Suborychodes* Kln.
 1st and 2nd abdominal segments furrowed . . . 12.

12.	Prothorax deeply furrowed	*Parorychodes* Kln.	
	Prothorax not furrowed, or slightly so at its base		13.
13.	Prorostrum narrow	*Orychodes* Pasc.	
	Prorostrum as broad as the head, indented in front of the mesorostrum	*Calorychodes* Kln.	

BELOPHERINAE.

1.	Prorostrum at its front edge not at all or only slightly enlarged, in any case not laterally produced		2.
	Prorostrum at its front edge with a lateral pointed projection		5.
2.	The whole rostrum above slightly toothed		3.
	Only the prorostrum toothed		4.
3.	Elytra at their sides with rows of punctures, not with lattice-like furrows	*Epicoenoreus* Senna.	
	Elytra with lattice-like furrows	*Euphenges* Calabr.	
4.	Mesorostrum with stout, oblique spines	*Desgodinsia* Senna.	
	Without spines	*Heteroblysmia* Kln.	
5.	Prorostrum with a stout lateral tooth		6.
	Without lateral tooth		7
6.	Prorostrum cylindrical	*Apocemus* Calabr.	
	Prorostrum of various shapes, but not cylindrical	*Hopliterrhynchus* Senna.	
7.	Basal joint of the antennae disfigured, coarse sculpture, teeth and spines, or laterally compressed	*Teraticorhynchus* Kln.	
	Basal joint more or less rounded		8.
8.	Prorostrum in front of the mesorostrum constricted, flat, triangular	*Ectocemus* Pasc.	
	Prorostrum not triangular		9.
9.	Front tibiae spined in the middle	*Pseudobelopherus* Calabr.	
	Without spines		10.
10.	Front legs conspicuously prolonged, rostrum about 4 times as long as the head; prorostrum without tooth	*Heterorhynchus* Calabr.	
	Front legs not prolonged, rostrum twice as long as the head, prorostrum toothed	*Anepsiotes* Kln.	

ITHYSTHENINAE.

1.	Elytra smooth, besides the suture only one rib, the following only in punctured lines		2.
	Ribs with regular lines of punctures, besides the suture no deep ribs	*Diurus* Pasc.	
2.	Antennae short, stout	*Plesiophocylides* Kln.	
	Antennae long slender		3.
3.	1st and 2nd abdominal segment furrowed, suture and 2nd rib present	*Gediocera*, Pasc.	
	Not furrowed, elytra only with suture, other ribs absent along the suture a pubescent line	*Achrionota*, Pasc.	

PSEUDOCEOCEPHALINAE.

1. Elytra on their hinder border prolonged . . .	*Opisthenoplus* Kln.	
Elytra not prolonged		2.
2. Elytra toothed at their base	*Hormocerus* Schoenh.	
Elytra not toothed at their base		3.
3. Besides the suture no rib present	*Metatrachelus* Kln.	
At least 2 other ribs present		4.
4. Hinder border of the eyes toothed, or a deep furrow from the occiput to the eye; head more or less cylindrical, tibiae narrow and slender.	*Holotrachelus* Kln.	
5. Hinder border of the eyes smooth or wavy, not toothed, no furrow: head short, straight or longer, oblong, tibiæ generally stout and broad	*Schizotrachelus* Lacord.	

PART II.

Notes on the Biology of the Brenthidae

BY

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Forest Entomologist.

The Brenthidae form a family of beetles, that is essentially characteristic of the forests of tropical and subtropical regions, with very few representatives in Europe and North America. It is therefore natural that little is known of the biology of the family, and the few published observations are to-day accepted with reserve. The earliest general account is that of Sharp (1901, 295), who qualifies his summary with the remark that "an uncertainty, almost complete, prevails as to the early stages of this family." Von Schonfeldt, who monographed the family in the Genera Insectorum and the Coleopterorum Catalogus in 1908, cites only two or three references to biology. Kleine (1922, 157) to whom we are indebted for reforms on the systematic side, states as late as 1922 :—" Our knowledge of the biological conditions among the Brenthidae is most miserable ....In general the pre-imaginal life-history must probably occur in the cambium of diseased trees. Whether the imagines later feed on herbaceous plants or whether they are flower-visitors, is still to be discovered. According to other information this is not impossible. Moreover not all Brenthids are xylophagous or phytophagous, a whole group is myrmecophilous. Still another mode of development may possibly occur ; we are not yet aware of it."

More recently Kleine published a note—Neuere biologische Beobachtungen bei Brenthiden (Kleine, 1923, 619-623)– in which a summary is given of the food-trees of Indian brenthids based on information in the Forest Research Institute, and attention is drawn to the present writer's discovery of the feeding-habits of the genus *Cyphagogus*. He divides the family into two groups, (*a*) phytophagous, and (*b*) myrmecophilous,—the latter containing only a few forms.

The phytophagous group may be sub-divided into two sections :—

(*a*) Rostrum similar in both sexes, never filiform in the female (*Calodrominæ* and *Stereoderminæ*).

(*b*) Rostrum dimorphic, variable in the male, filiform in the female, and hence suitable for boring (all other sub families except the *Amorphocephalinæ*).

Kleine expresses an opinion that the members of the first of the phytophagous sections should exhibit a different type of life-history on account of their morphological differences. This is borne out for the Calodrominae by the observations, that have been made on the genus *Cyphagogus* (*vide* pp. 3—7), of which at least ten species use the galleries of Scolytidæ and Platypodidæ for the purpose of oviposition. Here we find isophagy among wood-borers carried to a competitive degree at which it amounts to robbery or usurpation. In the Stereoderminæ, however, the instance of true wood-boring habits in *Cerobates tristriatus* (*vide* p. 8) appears to show that usurpation is not a necessary consequence of peculiar morphology.

According to Kleine the great majority of the phytophagous brenthids should be considered...... " in a certain sense as bark-beetles. Their capability for damage must however be only secondary, for it is explicitly stated in various thoroughly reliable records of tropical collectors, that they live on dead, dying or suppressed trees. In the case of more healthy material the development appears to take place only in the cambium, and in the case of rotten trees in the wood also." (l.c. 1923, 619).

On the other hand, the observations made by the writer suggest that the Indian species (at any rate) in the larval stage are true wood-borers and not bark-borers, and that their habitat is normally in felled or fallen timber and not in living trees. The adult beetles occur gregariously between the bark and wood of trees, that have been attacked by bark and sapwood-boring larvæ, (mainly Longicornia); they often hibernate, under dead bark in company with histerids, staphylinids and clavicornia, but may be found in most months of the year. The eggs appear to be deposited singly on the surface of the sapwood under the shelter of the wood dust and fibres in the excavations of surface-borers In many genera the female bores a hole in the wood with the mandibles for the reception of the egg. The larva constructs its own gallery radially into the wood, and feeds like the Lymexylonidæ and Platypodidæ on sap or saprophytic fungi growing in the gallery. Pupation usually occurs in a cell enlarged along the axis of tunnel, and emergence takes place *viâ* the site of oviposition, *e.g* *Cerobates* (*vide* pp. 8, 9). This simple type of life-history may be modified by the utilisation of the internal tunnels of other wood-borers, with the construction of larval galleries at right angles to the wall of the tunnel, as *e.g.*, the case of *Microtrachelizus* in the tunnels of *Hoplocerambyx spinicornis* (*vide* p. 10). A further modification occurs when the utilisation of the gallery of another wood-borer involves the ejection of the rightful occupant, *e.g.*, in the case of *Cyphagogus* and the Platypodidæ.

Since the life-cycle of brenthids progresses concurrently with those of primary wood-borers, the family should be ranked among the borers of freshly felled or fallen timber, rather than among those groups, that establish themselves only after the timber has lost a high proportion of its moisture, and has begun to decay.

The myrmecophilous group of brenthids includes two types; symphilines and robbers. The former live in association with ants nesting in the soil as well as in plants, and are characterised by the possession of exudatory organs. The latter are usually without excretory pores, but exhibit other anatomical modifications. Nothing is known of their larval habits.

The following biological notes on Indian species are arranged in systematic order; the geographical distribution is given as the majority of the records is new.

CALODROMINÆ.

CALODROMUS Guerin.

Calodromus mellyi Guer. has been taken in the galleries of shot-hole borers in *Vatica lanceæfolia*. Its habits appear to be similar to those of species of *Cyphagogus*.

Distribution: Coromandel Coast; U. Dihing Reserve, Lakhimpur, Assam; Katha, Burma, Andamans; Nicobars; Malacca; Sumatra; Borneo; Philippines

CYPHAGOGUS Parry.

A species of *Cyphagogus*, described by Lewis from Japan in 1883 was taken by him in "the holes pierced 6 or 8 inches into the trees by small wood-borers" (Lewis, 1884, 297). He comments on the structural modifications in the legs and thorax, which are of a type, that enables the beetles of species of *Cyphagogus* "to enter, pass freely through, and explore the confined recesses of galleries made in hard wood by borers of no bigger girth, but of more perfect cylindricity, than themselves." Two species of *Cyphagogus* were described in 1893 by Senna from the material obtained by Grouvelle in tobacco bales from Sumatra, one of which he named *tabacicola* (Senna, 1893, 294). Of this widely-distributed species Kleine notes, "according to Grouvelle's statement, it is a question of a species living on tobacco, which probably is also to be found on other herbaceous plants. Hence the dependence on forests is less marked and the possibility of distribution greater." (Kleine, 1921, 315). There is, however, little doubt, that in addition

to the clavicornia described by Grouvelle the imported tobacco harboured numerous species of beetles, that do not feed upon it, some of them being true wood-borers, as for example *Platypus biuncus, Phloeosinus cribratus, Xyleborus semigranosus, Xyleborus scabripennis,* etc., Scolytidæ described by Blandford in 1896. *Xyleborus semigranosus* is very common in India and has been bred at the Forest Research Institute from a large number of species of forest trees.

In his revision of the genus *Cyphagogus* Kleine says, "the circumstances, that the females do not have a filiform rostrum, allows one to conclude, that they are not wood-borers but live on herbaceous plants." (Kleine, 1921, 294). The observations of the wirter on the Indian species of the genus do not confirm this hypothesis, but show that they are true wood-borers in the larval stage in so far that they prepare their own larval and pupal galleries. In the adult stage they are competitors with other wood-borers for breeding-sites, laying their eggs in the galleries of shot-hole-borers of the families Platypodidæ and Scolytidæ. It is possible that the *Cyphagogus* may not wait until the galleries of their shot-hole-boring hosts are vacated, but may kill or eject the inhabitants of those in which tenants are encountered. The mandibles of *Cyphagogus* are suitable for successful attack on the posterior portion of a platypodid beetle, whose chief means of defending the brood-gallery is by interposing its body as a living plug.

Kleine (1923, 620) terms this type of life-history as "Brutparasitismus der ziemlich rucksichtslos und robust ausgefuhrt wird." Escherich (1923, 432) uses the term "Wohnungsparasitismus" for a similar state in *Crypturgus.* It is scarcely social parasitism but rather an isophagous competition that has reached a degree at which it becomes robbery or usurpation. A similar inference has been made by the writer for species of *Phænomerus* (Cossonidæ), that occur under identical conditions (*c.f.* Marshall, 1916, F.B.I., 20).

Cyphagogus westwoodi Parry.

The possibility that the genus *Cyphagogus* might possess other than a normal wood-boring habit occurred to the writer in 1915 by the frequent discovery of individuals of *Cyphagogus westwoodi* and *Cyphagogus tabacicola* in the galleries of *Crossotarsus squamulatus* infesting sundri (*Heritiera Fomes*) trees in the deltaic forests of the Sunderbans. The *Cyphagogus* were observed in the entrance tunnels of the *Crossotarsus* and of other platypodids, sometimes near the partially destroyed bodies of the brood-parents. As there was no other evident reason for the death of the platypodid it was concluded that the brenthids were predaceous.

In June, 1921, *Cyphagogus westwoodi* and *Cyphagogus obconiceps* were bred from the wood of morhal (*Vatica lanceæfolia*) collected a month previously in Upper Dihing Reserve, Lakhimpur Division, Assam. The brenthid galleries were found to be grouped in clusters or whorls originating from the horizontal, radial, tunnels of *Crossotarsus saundersi.* The gallery of the *Crossotarsus* is in places slightly enlarged, and irregularly pitted with niches, that are possibly the sites of oviposition. From these points the *Cyphagogus* larval work extends in short curved tunnels of increasing diameter, and terminates in pupal cells closed by plugs of dust and fine fibres. No one of the galleries exceeded five times the length of the beetle. Pupæ of *Cyphagogus westwoodi* and one *Cyphagogus planifrons* were recovered from the specimen of morhal. Galleries from which the beetles have successfully emerged are, of necessity, enlarged towards their proximal end, to obtain access to the egg-tunnel by which escape from the tree takes place. (See plate III, fig. 2.)

Cyphagogus westwoodi has also been taken from *Poinciana elata* in the Nilgiris.

Distribution. Ceylon ; Cochin ; Nilgiris ; Kanara, Bombay ; Lakhimpur, Sibsagar, Assam ; Sunderbans, Bengal ; Burma ; Indo-china ; Perak ; Sumatra ; Java ; Borneo.

Cyphagogus buccatus Kleine.

The gallery of a platypodid (? *Crossotarsus indicus*) in teak (*Tectona grandis*) collected in West Salween Division, Burma, shows a group of brenthid tunnels at a distance of ½ to 1 inch from the surface of the sapwood. The larval tunnels extend on all sides from the wall of the platypodid gallery for variable distances, ⅛th to ½ an inch, before the pupal cell is reached ; they are filled with fine wood-dust more closely-packed at the mouth of the pupal cell. While the pre-pupal portion of the tunnel may run horizontally or curve, the pupal chamber appears always to lie vertically in the trend of the fibres. Two dead beetles and obscure larval remains were recovered in the pupal chambers.

Cyphagogus buccatus has been bred from *Shorea robusta* attacked by shothole borers (R.R.D. 197, 105 and 252, 126) in Goalpara, Assam.

Distribution : Ceylon ; Pathri, Saharanpur, United Provinces ; Goalpara, Assam ; North Toungoo, West Salween, Burma ; Andamans ; Perak ; Sumatra ; Java ; Borneo.

Cyphagogus confertulus Kleine.

Known only from *Mesua ferrea* in Upper Dihing Reserve, Lakhimpur, Assam.

Cyphagogus corporaali Kleine.

In December, 1917, a log of *Butea frondosa* was collected from an old felling at Pathri, Saharanpur Division, United Provinces; it showed signs of attack by *Platypus solidus* and *Xylotrechus smei* and was caged on 18th December 1917. In February and April, 1918 numbers of *Cyphagogus corporaali* emerged. Examination of the wood in 1923 revealed the existence of groups of short galleries, mainly in a vertical plane in the neighbourhood of the horizontal galleries of *Platypus solidus*. The former were filled with a black dust due to the sporulation and disintegration of the fungi that develop in decaying dhak wood. Their identity was fixed by the occurrence of dead immature beetles and pupæ of *Cyphagogus corporaali*. The galleries were observed to originate at short intervals from the wall of the main horizontal *Platypus* gallery, from which they curve outwards and vertically upwards or downwards for a distance of up to an inch. The terminal portion forms a pupal chamber in which the insects occur with their heads directed towards the *Platypus* gallery, through which the successful individuals make their escape. The pre-pupal portion of the gallery is packed with fine normally-coloured wood-dust. The diameter of the pupal chamber is slightly greater than that of the *Platypus* gallery, but the holes bitten by the emerging beetles in the walls of the latter are slightly smaller and vary with the size of the individual. (See Plate III, fig. 1).

Cyphagogus corporaali has been taken from *Bauhinia purpurea*, *Bombax malabaricum* and *Butea frondosa* in Saharanpur Division, United Provinces, and from *Tectona grandis* in Nilambur, Madras.

Distribution: Ceylon; Madras; North Gujerat; Saharanpur, United Provinces; Burma; Java; Borneo.

Cyphagogus eichhorni Kirsch.

In *Bombax malabaricum* in Singhbhum.

Distribution: Singhbhum, Bihar and Orissa; Patkai Mts., Assam; Burma; Andamans; Malacca; Sumatra; Borneo.

Cyphagogus gladiator Kleine.

In *Mallotus alba* and *Mesua ferrea* in Nambor Reserve, Sibsagar, Assam.

Distribution: Sibsagar, Assam; Perak; Sumatra; Borneo; Philippines.

Cyphagogus obconiceps Senna.

Bred from platypodid galleries in *Vatica lanceæfolia* from Upper Dihing Reserve, Lakhimpur, Assam—The larval work of *Cyphagogus obconiceps* is similar to that of *Cyphagogus westwoodi* (*vide ante*).

Distribution : Lakhimpur, Assam ; Malacca ; Sumatra ; Borneo.

Cyphagogus planifrons Kirsch.

Taken as beetle from *Mesua ferrea* and as mature pupa from pupal chamber constructed alongside platypodid galleries in *Vatica lanceæfolia*—both in Assam.

Distribution : Nilgiris ; Sibsagar, Lakhimpur, Assam ; Siam ; Malacca ; Sumatra ; Borneo ; Philippines.

Cyphagogus simulator Senna.

From *Vatica lanceæfolia* in Assam.

Distribution : Sibsagar, Lakhimpur, Assam ; Penang ; Sumatra ; Java.

Cyphagogus tabacicola Senna.

From platypodid galleries in *Heritiera Fomes* in the Sunderbans, *Vatica lanceæfolia* in Assam and *Melanorrhoea usitata* in Burma.

Distribution : Niligiris ; Sunderbans, Bengal ; Sibsagar, Assam ; Hsipaw, N. Shan States ; Andamans ; Penang ; Sumatra ; Java ; Borneo.

EUSEBUS Kleine.

Eusebus adelphus Kolbe has been found in *Butea frondosa* attacked by *Xyleborus parvulus* Eichh.

Distribution : Ceylon ; Pathri, Saharanpur, U.P.

PSEUDOCYPHAGOGUS Desbrocher des Loges.

Pseudocyphagogus squamifer Desbr. was bred from a log of *Dipterocarpus pilosus* that was attacked by an undescribed platypodid, with which were associated *Phœnomerus reclinatus* Mshl. and *P. sundevalli* Boh. The log (R. R. D. 876, 20. 227) collected in Upper Dihing Reserve, Lakhimpur, on 26th May 1921 and caged on 11th June 1921 yielded Platypodidæ from 14th June, 1921 to 27th July 1921. *Pseudo cyphagogus* bred out from 16th March 1922 to 17th June 1922,—the maximum emergence occurring in May, and indicating an annual generation.

The larval galleries assigned doubtfully to *Pseudocyphagogus* were not associated with those of the shot-hole borer but occurred in the sapwood in the form of short radial tunnels connected with vertical and horizontal branches of variable diameter.

Two specimens of *Pseudocyphagogus squamifer* were bred from *Shorea assamica* originating from Margerita, Assam (R.R.D. 934, 75, 143) in May 1922 from a log caged in September 1921.

Distribution : Upper Dihing Reserve, Lakhimpur, Assam ; Andamans ; Siam ; Penang ; Borneo.

ALLÆOMETRUS Senna.

Allæometrus breviceps Senna was taken in *Shorea robusta* in Jalpaiguri and Buxa Divisions, Bengal.

Distribution : Kanara, Bombay ; Buxa, Jalpaiguri, Bengal ; Garo Hills, Assam ; Indo-China ; Sumatra ; Java ; Borneo ; Formosa ; Queensland.

Allæometrus deformis Kleine is recorded by Stebbing (1914, 391) under the name of *Zemioses* sp., in tunnels in the wood of *Shorea robusta.*

Distribution : Goalpara, Assam.

STEREODERMINAE

CEROBATES Schœnherr.

With reference to specimens of *Cerobates sexsulcatus* Motsch. taken in Cambodia and Cochin China Kleine says (1922, 157). "According to the statement of the collector the insects develop under the bark of trees and the imagines were caught in a garden on water-cresses". Beyond the fact that the beetles are to be found commonly under dead bark no further information on the life-history of members of this large genus has been published.

Observations have been made on the biology of *Cerobates tristriatus*, in an oasis in savannah forest at Pathri, Saharanpur, December 1917, in branches of the fallen crown of *Bombax malabaricum* attacked by *Plocæderus obesus, Macrotoma crenata, Mecistocerus bardus, Rhadinomeris bombacis* and *Xyleborus perforans.*

The beetles apparently lay eggs singly on the surface of the sapwood of trees with partially decayed bark : the larva bores a radial gallery into the soft wood. In its early stages the gallery is very slightly tapered, increasing in diameter from the fine needle-hole on the surface of the wood towards the centre of the log. Its final length does not exceed

two inches ; its course in the horizontal plane is straight or slightly curved ; it contains fine wood-dust at the outer end and is empty in the newer portions. In its later stages the gallery is widened uniformly throughout with the growth in size of the larva except at the extreme outer end, which remains as a fine needle-hole. The diameter is sufficiently great to permit the larva to turn freely in the gallery. The products of excavation are apparently ejected at intervals, although near the time of pupation it may contain a quantity of moist excrement and wood-dust, which readily becomes discoloured and permeated with mycelium.

The galleries occur in close groups more or less intermingled but not communicating or branching. Sometimes they intersect *Xyleborus* galleries so that *Cerobates* larvæ may be found in *Xyleborus* gallaries and the scolytids may wander into the brenthid galleries.

In the development of its gallery *Cerobates* resembles the lymexylonid *Hylocoetus* and apparently its food is similarly sap and moulds.

From a *Bombax* log caged in December, 1917, *Cerobates* emerged between the 17th March and 2nd April of the following year the swarm occurring most strongly between 20th and 29th March.

A description of the larva is given in part III, pp. 1—3, Plate IV.

Cerobates sexsulcatus has been found boring in felled *Butea frondosa* attacked by *Xyleborus parvulus*, at Ranipur, Siwaliks, February, 1924. The larval tunnel is similar to that of *Cerobates tristriatus* and a description of the larva is given by the Systematic Entomologist on p. 5, Part III. (See also Plate III, fig. 3).

Distribution : Ceylon ; India ; Burma , Indo-China ; Malay Archipelago ; New Guinea.

TRACHELIZINÆ

TRACHELIZUS Schœnherr.

Trachelizus bisulcatus F. has been bred from caged logs of *Bombax malabaricum, Butea frondosa, Ficus asperrima, Ficus glomerata* and *Ficus religiosa*. The beetles occur commonly under the thick decaying bark of fallen trees.

Distribution : Ceylon ; British India ; to Australia.

HIGONIUS Lewis.

Higonius cilo Lewis has been found in *Castanopsis tribuloides* and *Milletia auriculata* in Assam.

Distribution : Sibsagar, and Makum Reserve, Lakhimpur, Assam ; Burma ; Philippines ; Formosa ; Japan.

Higonius crux Oliff. is attracted to newly felled *Tectona grandis*.

Distribution : North Toungoo, Burma ; Andamans : Tongking ; Penang ; Sumatra ; Borneo.

ARAIORRHINUS Senna.

Araiorrhinus beesoni Kleine was taken under the bark of *Tectona grandis*.

Distribution : Mohnyin Reserve, Katha, Burma.

MICROTRACHELIZUS Senna.

Microtrachelizus accomodatus Kleine has been bred from *Shorea assamica* in Lakhimpur Division and from *Vateria indica* in North Malabar, Madras.

Distribution : North Malabar, Madras ; Margherita, Lakhimpur, Assam ; Perak ; Borneo.

Microtrachelizus apertus Kleine has been obtained from *Dalbergia assamica*, *Ehretia acuminata*, and *Mesua ferrea* in Assam ; its habits are presumably the same as those of the following species.

Distribution : Gopaldhara, Darjeeling, Bengal ; Nambor Reserve, Sibsagar, Upper Dihing Reserve, Lakhimpur, Assam.

Microtrachelizus beneficus Kleine.

This species was bred from a log of *Shorea assamica* (R. R. D. 934,75, 143) from Margherita, Lakhimpur Division, Assam caged on 12th October 1921. The timber was heavily attacked by *Xyleborus perforans* Woll., *Xyleborus parvulus* Eichh., *Xyleborus shoreæ* Stebb., *Diapus* sp. nov., *Dendrotrogus angustipennis* Jord., *Dialeges pauper* Pasc., *Hoplocerambyx spinicornis* Newm. associated with *Phænomerus brevirostris* Mshl., *Phænomerus sundevalli* Boh., *Suborychodes intermedius* Kleine, and *Pseudocyphagogus squamifer* Desbr.

Although associated with shot-hole borers, *Microtrachelizus accomodatus* is not a gallery-parasite of either of the species mentioned. On the contrary, it makes use of the pre-pupal tunnels of *Hoplocerambyx spinicornis* as sites for oviposition, apparently a case of synœcy.

The parents enter the bark of the bored log by means of ejection-holes, e c., and while the mature larvæ of *Hoplocerambyx spinicornis* are hibernating they penetrate the tunnels leading from the sap-wood to the pupal chamber in the heart-wood. The pre-pupal tunnels are usually filled with coarse fibres derived from the heart-wood, but these

are not packed tightly enough to offer obstruction to the brenthid. Eggs are laid singly but abundantly on the wall of the tunnel (*vide* Plate III fig. 5 which shows the distribution of oviposition sites in the pre-pupal tunnel). The larvæ hatching out excavate tunnels, one to two inches long, that curve outwards in a whorl from the *Hoplocerambyx* tunnel (*vide* Plate III fig. 4), Presumably their food is sap and saprophytic fungi, as the larvæ evidently move freely to and fro and the abandoned tunnels are found to contain mainly mildewed excrement with very little wood-dust. Pupation takes place in a slightly enlarged chamber at the base of the larval gallery ; the pupal chamber is plugged at both ends before the larva pupates. The beetle emerges by enlarging the orifice of the larval gallery and escapes into the *Hoplocerambyx* tunnel.

The emergence period of *Microtrachelizus beneficus* is prolonged for a year with two marked swarms occurring from 15th November to 30th December, and 15th April to 15th June, the latter being less abundant. The distribution by six-day periods is as follows :–

1921 --		
12, October	Log caged.	
14-19, October	2	
20-25, October	1	
26-31, October	1	
13-18, November	3	
19-24, November	19	
25-30, November	15	
1-6, December	8	57 swarm
7-12, December	3	
13-18, December	4	
19-24, December	4	
25-30, December	1	
1922		
12-17, January	2	
18-23, January	1	
23-28, February	1	
1-6, March	1	
7-12, March	1	
18-23, April	1	
24-29, April	2	
30 5, May	1	
6 11, May	2	25 swarm
12-17, May	4	
18-23, May	5	
24-29, May	8	
30-4, June	2	
23-28, June	1	
29-3, July	1	
22-27, July	1	

The species of shot-hole borers breeding in the same log have emergence-periods, that indicate different types of development from that of the brenthid.

Diapus sp. nov. was emerging when the log was caged; the swarm reached its maximum at the end of October, and gradually decreased in abundance throughout November and December. After the first of January, 1922, only a few stragglers appeared.

Xyleborus perforans was also swarming in the middle of October, but ceased through the cold months, and completed its emergence n a small swarm from the end of February to the end of March, 1922.

Xyleborus shoreæ showed only a feeble emergence from October to March, but swarmed strongly from 15th March to 30th April.

It is possible that the two swarm-periods represent two generations of *Microtrachelizus beneficus* If that is so, the May brood must normally use another host than *Hoplocerambyx spinicornis* (whose pre-pupal tunnels are available only in the autumn and cold weather), whenever the timber dries up fast enough to make it unsuitable for re-attack.

Distribution : Margherita, Lakhimpur Division, Assam.

HOPLOPISTHIUS Senna.

Hoplopisthius trichimerus Senna from *Dalbergia assamica.*

Distribution : Upper Dihing Res., Lakhimpur, Assam; Burma; Perak; Sumatra; Java, Borneo, Philippines; Formosa.

CARCINOPISTHIUS Kolbe.

Carcinopisthius maculatus Senna from *Dipterocarpus pilosus.*

Distribution : Nakachari, Sibsagar, and Garo Hills, Assam; Burma; Sumatra.

Carcinopisthius oberthuri Senna from *Dipterocarpu pilosus.*

Distribution : Nakachari, Sibsagar. Assam; Burma; Formosa.

ARRHENODINÆ.

PROPHTHALMUS Lacordaire.

Prophthalmus tridentus F. is recorded by Stebbing (1914, 391 fig. 263) from *Pterospermum acerifolium* in Balipara Res., Darrang. He found two pupæ in pupal chambers in fresh, moist, sap-wood. "The chambers were elongate and parallel to the long axis of the tree, and about half an inch deep in the sap-wood."

Distribution : Darrang, Assam ; Andamans ; Perak ; Sumatra ; Java ; Borneo ; Celebes.

BARYRRHYNCHUS Lacordaire.

Baryrrhynchus miles Boh. is known only from "Naga kola" (? *Alphonsea ventricosa*) in Nambor Res., Sibsagar, Assam.

Distribution : Ceylon ; Trichinopoli ; Nilgiris ; Nepal ; Darjeeling, Buxa. Kurseong, Chittagong Hills, Bengal ; Garo Hills, Khasia Hills ; Kalimpong ; Sibsagar, Assam ; Manipur ; Burma ; Indo-China ; Hainan Island ; Java ; Borneo.

CAENORYCHODES Kleine.

Cænorychodes planicollis Wlk. from *Alphonsea ventricosa* in Assam and *Ficus* sp. in the Central Provinces and *Poincianiaclata* in the Nilgiris.

Distribution : Ceylon ; Palnis ; Nilgiris ; Coorg ; Khandesh, Kanara, Bombay ; South Raipur, Central Provinces ; Kheri, United Provinces ; Kurseong, Darjeeling. Sikkim ; North Cachar, Sibsagar, Assam ; Katha, Burma , Andamans ; Siam ; Indo-China ; Formosa.

SUBORYCHODES Kleine.

Suborychodes intermedius Kleine has been bred from *Shorea robusta* in the forests of Dehra Dun division. A log caged on 19th December 1919 (R. R. D. 657, 271, 198) yielded beetles in June 1920, and another log caged 12th April, 1921 (R. R. D. 849, 2, VI) yielded beetles in June 1921).

Pieces of *Shorea assamica* from Margherita, Lakhimpur Division caged on 12th October 1921 (R. R. D. 934, 75, 143) established a definite swarm period for *Suborychodes intermedius* lasting from 15th April to 15th June, 1922 with the maximum emergence in the first week of May.

Arranged by six-day periods individuals appeared on the following dates :—

1921—	
12, October	Log caged.
16-21, April	4
22-27, April	3
28-3, May	11
4-9, May	7
10-15, May	1
16-21, May	1
22-27, May	2
28-2, June	1
3-8, June	2

The timber was also attacked by numerous shot-hole borers, longicorns and other borers, so that the brenthid galleries were obscured.

PARORYCHODES Kleine.

Parorychodes cereus Kleine from *Alphonsea ventricosa.*
Distribution : Nambor Res., Sibsagar, Assam.

PSEUDOCEOCEPHALINÆ.

OPISTHENOPLUS Kleine.

Opisthenoplus cavus Wlk. has been bred from *Shorea robusta* in Dehra Dun and taken also from *Odina wodier* and *Kydia calycina.*

Distribution : Ceylon ; Nilgiris ; Kanara, Bombay ; Dehra Dun, Gonda, United Provinces ; Garo Hills, Lakhimpur, Assam ; Burma ; Andamans ; Indo-China ; Penang ; Sumatra ; Borneo.

Opisthenoplus fascinatus Kleine is known from *Butea frondosa, Terminalia belerica*, and *Terminalia chebula* in Dehra Dun. The species was erroneously recorded by Stebbing (1914, 390) as *Ceocephalus carus* (sic) Walk.

Distribution : Dehra Dun, Siwaliks, Saharanpur, United Provinces ; Sumatra ; Formosa ; Philippines.

HORMOCERUS Schoenherr.

Hormocerus reticulatus F. The biology of this widely-distributed species remains undiscovered except for the knowledge that it is frequently associated with *Bombax malabaricum*. It has been bred out of *Bombax malabaricum* from Singhbhum, Bihar and Orissa. Stebbing (1914, 389) records it from *Castanopsis tribuloides.*

Distribution : Ceylon ; British India to Australia.

LIST OF SPECIES OF TREES WITH THE ASSOCIATED SPECIES OF BRENTHIDAE.

ALBIZZIA LUCIDA Benth.

Cerobates sexsulcatus M.

ALPHONSEA VENTRICOSA Hook. F. et Th.

Baryrrhynchus miles Boh.
Canorychodes planicollis Wlk.
Parorychodes cereus Kleine.

ARTOCARPUS LAKOOCHA Roxb.

Cerobates fossulatus M.

BAUHINIA PURPUREA Linn.

Cyphagogus corporaali Kleine.

BOMBAX MALABARICUM Dc.

Cerobates tristriatus F.
Cyphagogus corporaali Kleine.
Cyphagogus eichhorni Kirsch.
Hormocerus reticulatus F.
Trachelizus bisulcatus F.

BUTEA FRONDOSA Roxb.

Cerobates sexsulcatus M.
Cerobates tristriatus F.
Cyphagogus corporaali Kleidne.
Eusebus adelphus Kolbe.
Opisthenoplus fascinatus Kleine.
Trachelizus bisulcatus F.

CASTANOPSIS TRIBULOIDES ADC.

Higonius cilo Lewis.
Hormocerus reticulatus F.

DALBERGIA ASSAMICA Benth.

Hoplopisthius trichimerus Senna.
Microtrachelizus apertus Kleine.

DIPTEROCARPUS PILOSUS Roxb.

Carcinopisthius maculatus Senna.
Carcinopisthius oberthuri Senna.
Pseudocyphagogus squamifer Desbr.

DYSOXYLUM BINECTARIFERUM HOOK.

Cerobates sumatranus Senna.
Cerobates sexsulcatus M.

EHRETIA ACUMINATA Br.

Microtrachelizus apertus Kleine.

ERYTHRINA INDICA Lam.

Trachelizus bisulcatus Land.

FICUS SP.

Cœnorychodes planicollis Wlk.

FICUS ASPERRIMA Roxb.

Trachelizus bisulcatus F.

FICUS GLOMERATA Roxb.

Trachelizus bisulcatus F.

FICUS RELIGIOSA Linn.

Trachelizus bisulcatus F.

HERITIERA FOMES Buch.

Cyphagogus tabacicola Senna.
Cyphagogus westwoodi Parry.

KYDIA CALYCINA Roxb.

Opisthenoplus cavus Wlk.

MALLOTUS ALBA Muell.

Cyphagogus gladiator Kleine.

MELANORRHOEA USITATA Wall.

Cyphagogus tabacicola Senna.

MESUA FERREA Linn.

Cyphagogus confertulus Kleine.
Cyphagogus gladiator Kleine.
Cyphagogus planifrons Kirsch.
Microtrachelizus apertus Kleine.

MILLETTIA AURICULATA Baker.

Higonius cilo Lewis.

ODINA WODIER Roxb.

Opisthenoplus cavus Wlk.

POINCIANA ELATA Linn.

Caenorychodes planicollis Wlk.
Cyphagogus westwoodi Parry.
Prophthalmus delesserti Pow.
Trachelizus bisulcatus Lund.

PTEROSPERMUM ACERIFOLIUM Willd.

Prophthalmus tridentatus F.

SHOREA ASSAMICA Dyer.

Microtrachelizus accomodatus Kleine.
Microtrachelizus beneficus Kleine.
Pseudocyphagogus squamifer Debr.
Suborychodes intermedius Kleine.

SHOREA ROBUSTA Gaertn. f.

Allæometrus breviceps Senna.
Allæometrus deformis Kleine.
Cyphagogus buccatus Kleine.
Opisthenoplus cavus Wlk.
Suborychodes intermedius Kleine.

TECTONA GRANDIS Linn.

Araiorrhinus beesoni Kleine.
Cyphagogus buccatus Kleine.
Cyphagogus corporaali Kleine.
Higonius crux Oliff.

TERMINALIA BELERICA Roxb.

Opisthenoplus fascinatus Kleine.

TERMINALIA CHEBULA Retz.

Opisthenoplus fascinatus Kleine.
Opisthenoplus cavus Walk.

TERMINALIA TOMENTOSA W. et. A.

Opisthenoplus cavus Walk.

VATERIA INDICA Linn.

Microtrachelizus accomodatus Kleine.

VATICA LANCEÆFOLIA Bl.

Calodromus mellyi Guer.
Cyphagogus obconiceps Senna
Cyphagogus planifrons Kirsch
Cyphagogus simulator Senna.
Cyphagogus tabacicola Senna.
Cyphagogus westwoodi Parry.

ADDENDA : *Recent records include* :—

POINCIANA ELATA.
Cerobates concisus Kleine.

SHOREA ROBUSTA.
Higonius crux Ollif.

STERCULIA VILLOSA.
Microtrachelizus apertus Kleine.

DESCRIPTION OF PLATE III.

THE TUNNELS OF BRENTHIDAE.

Fig 1. Larval tunnels of *Cyphagogus corporaali* originating from a gallery of *Platypus solidus* in *Butea frondosa*.

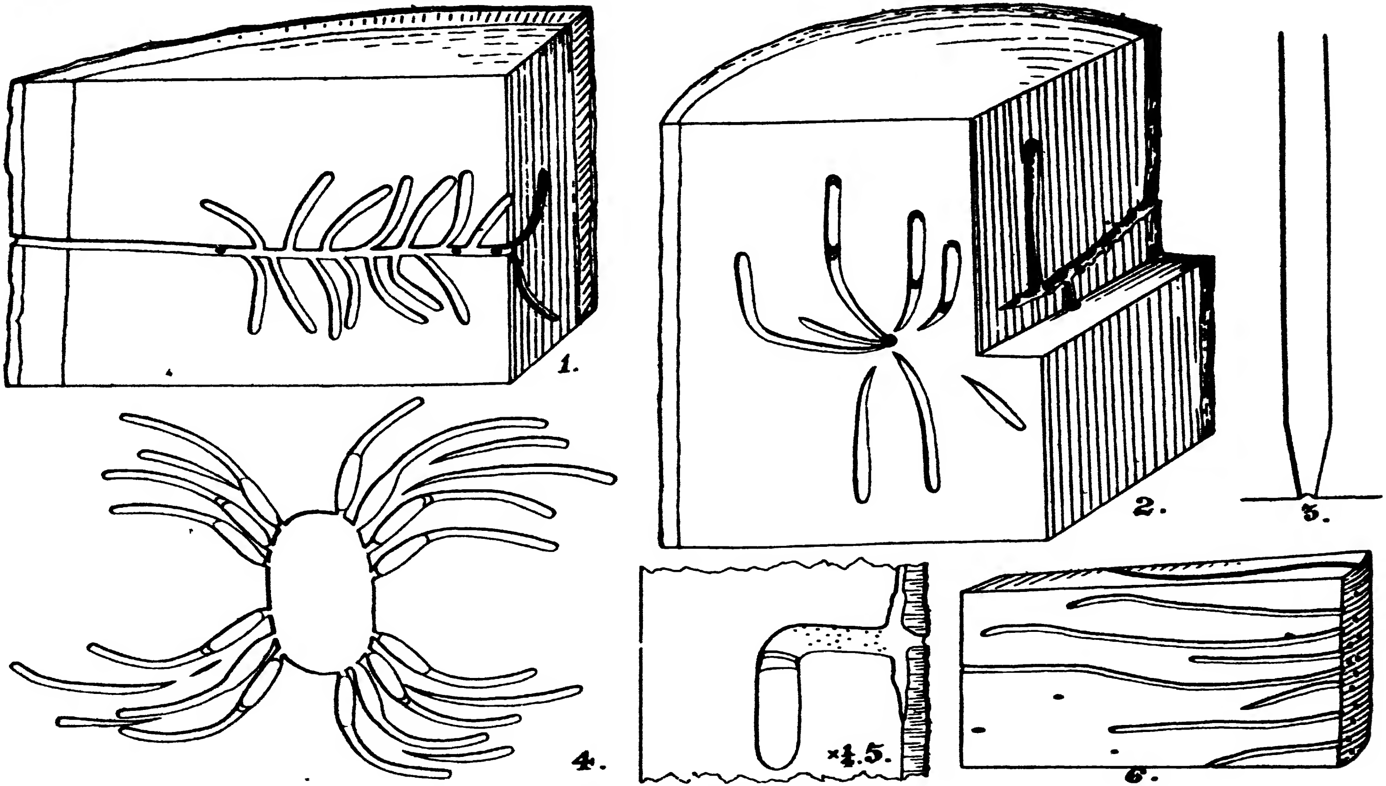
" 2. Larval tunnels of *Cyphagogus westwoodi* radiating from a gallery of *Crossotarsus* sp. in *Vatica lanceaefolia*. Note irregular pitting of the *Crossotarsus* gallery and the pupal cells of *Cyphagogus* at the end of the larval tunnels.

" 3. Longitudinal section of a *Cerobates* tunnel showing the apex narrowed towards the outer surface of the sapwood

" 4. Transverse section of the prepupal tunnel of *Hoplocerambyx spinicornis* in *Shorea assamica* showing the origin and trend of the tunnels of *Microtrachelizus beneficus*. Note location of pupal cells.

" 5. Longitudinal section of the prepupal tunnel and pupal chamber of *Hoplocerambyx spinicornis* showing the location of the exit holes of *Microtrachelizus beneficus*.

" 6 Longitudinal section of tunnels of *Cerobates tristriatus* in *Bombax malabaricum*.



TUNNELS OF BRENTHIDÆ.

PART III.

Description of (*a*) the larva of *Cerobates tristriatus* Lund. (*b*) the larva of *Cerobates sexsulcatus* Motsch (*c*) the pupa of *Cyphagogus corporaali* Kleine.

BY

J. C. M. GARDNER, I.F.S., A.R.C.S., D.I.C., F.E.S.

Systematic Entomologist.

(*a*) CEROBATES TRISTRIATUS. Lund.

LARVA.

(Pl. 4, figs. 1-8.)

Material. –About thirty larvæ, ex *Bombax malabaricum*, collected by Dr. C. F. C. Beeson at Pathri, Saharanpur, U. P., 15th December 1917.

Length.- About 8 mm from head to anus when in normal curved position ; width about 1 mm.

Colour. –White with head and small patches on prothorax and metathorax yellow to brown. Skin soft, glabrous except for a few rather long setæ on head and terminal segment, and a few short hairs on remainder of body.

Form.—Widely cyrtiform, cylindric, elongate ; thoracic segments larger than abdominal segments. Epipleural region protruberant along sides of body. With three pairs of leg like structures.

Head Capsule (*Pl. 4, figs. 5, 7*).—Outline circular posteriorly ; slightly longer than broad ; no posterior emargination.

Epicranial halves meeting dorsally, each half with seven or eight long setæ ; epicranial suture about half length of capsule.

Frons (*Pl. 4, fig. 7, f*) shield shaped ; with five pairs of setæ and two pairs of small circular pits, frontal sutures sinuate posteriorly and anteriorly deflected by antennal ring laterally to meet pleurostoma. *Epistoma* represented by thickened anterior margin of frons, nearly straight, with a stronger chitinous thickening on each side to receive dorsal mandibular articulations ; with two pairs of setæ projecting over clypeus.

Pleurostoma represented by thickened edge of capsule between dorsal and ventral mandibular condyles. *Occipital foramen* (*Pl. 4, fig.*

5, *of*) triangular, sides curved, the anterior, transverse side being the longest ; length of foramen slightly less than half that of the head ; with a median vertical plate, the occipital apodeme, arising from posterior margin of epicranial suture and extending nearly half way across foramen. A strong bridge one fourth as long as the occipital separates this foramen from the transverse oval anterior foramen ; this bridge anteriorly with two approximate strong tentorial projections forming base of tentorial arms.

The *hypopharyngeal bracon* (*Pl. 4, fig. 5, hy. br.*) is a chitinous bar bridging the anterior ventral margin of the head capsule between the ventral mandibular condyles.

Antenna (*Pl. 4, fig. 2*). Just posterior to pleurostoma ; represented by a small circular membranous cushion bearing on its summit three or four minute papillæ and a slender slightly tapering terminal joint ; width of antennal ring about three-fifths that of labium. Length of terminal joint less than 1/4th width of labium.

Clypeus. Transverse, trapezoidal, posteriorly wider than labium, posterior angles attached to epistoma by strong chitinous brackets.

Labrum (*Pl. 4, fig. 7, lbr.*). Rectangular, slightly broader than long with a lateral dorsal prominence on each side reaching about half way to apex of labium and bearing two setæ, one long and one short ; median part of anterior margin produced into a wide lobe ; anterior margin with about six small setæ near middle and one small seta near apex of each epipharyngeal rod.

Mandibles (*Pl. 4, fig. 5, md.*). Seen from side, triangular longer than wide ; with three teeth, namely an apical tooth, a second one just above and posterior to the first, and a third blunt tooth near middle of dorsal edge ; lateral face with two short setæ.

Maxilla (*Pl. 4, fig. 3*). Projecting beyond mandibles. *Cardo* (*ca*) distinct about half as long as stipes and mala together, apparently formed of two pieces. *Stipes* (*st*) fused with the single lobe (mala) and palpifer to form an elongate structure which has a rectilinear outer edge, and is about three times as long as its greatest width, this structure with three large and one minute setæ near middle. *Mala* (*ma*) single, represented by the rather slender bluntly rounded anterior projection of the stipital structure ; mala armed on dorsal surface with a longitudinal row of about fourteen acute mesad setæ, the anterior setæ being lanceolate acuminate and short while the posterior 5 setæ are longer and aciculate. *Palpifer* not defined. *Palpus* (*mp*) two jointed, projecting beyond mala ; basal joint slightly wider than long with a single seta near apex ventrally ; terminal joint cylindrical bluntly rounded at apex, shorter than basal joint and slightly longer than wide.

Labium (*Pl. 4, fig. 3*).—*Mentum* (*mt*) not demarcated from submentum (*sm*) but fused with it to form a large fleshy trapezoidal plate continuous posteriorly with prothoracic skin; this plate with three setæ on each side. *Stipes labii* (*stl*) posteriorly strengthened by a fairly distinct semi-circular chitinous band with a weak median caudad projection; with a short stout seta on each side near posterior margin and on the sub-rectangular area between these setæ and labial palpi a patch of minute setæ or asperities. There is no distinct labial palpiger. *Labial palpus* (*lp*) two jointed, first joint wider than longer; terminal joint cylindrical, bluntly rounded at apex, longer that terminal joint of maxillary palpus. *Ligula* (*li*) transverse armed with two pairs of short setæ, one pair being apical.

Maxillular area with two elongate setose lobes reaching nearly to apex of ligula and separated from one another by a fine groove; the external margins of these lobes with a chitinous thickening posteriorly where junction with the hypopharyngeal bracon occurs.

Thorax (*Pl. 4, fig. 1*). *Prothorax* with distinct yellowish trapezoidal tergal plate which is about three times as wide as long and has about eight setæ on anterior margin and one seta on each lateral margin; prescutal area short, transverse. *Mesothorax* and *metathorax* each with two distinct transverse dorsal areas, the anterior being the prescutum and the posterior the scuto-scutellum; prescutum of mesothorax small, lenticular; scuto-scutellum of mesothorax large, transverse and deeply emarginate behind where the protruberant prescutum of metathorax projects into it, the lateral lobes thus formed armed posteriorly with small transverse asperities; dorsal areas of metathorax with minute asperities; alar area and epipleurum of meso-and metathorax sub-oval, swollen and with minute asperities anteriorly. The single thoracic spiracle large oval, borne on a small pre epipleurite forced into prothorax from mesothorax width about two thirds length. Each thoracic segment with a pair of leg-like structures or legs each leg (*Pl. 4, fig. 6*) consisting of a stout basal joint armed with four setæ and a distal conical joint with one long and four shorter setæ at its apex*. Transverse divisions of sternum indistinct.

Abdomen.—Each of first six segments divided dorsally into four transverse areas, the anterior area of each segment minutely asperate. Each segment with protruberant elongate epipleural and hypopleural areas; epipleurum parallel sided, not quite reaching anterior margin of segment, with a single seta; hypopleurum with two or three small

* Some of the smaller larvæ in this material have only two apical setæ on the legs.

setæ; these protruberances larger and more irregular on last three segments. Spiracles eight pairs, sub-circular, about two-thirds as long as thoracic spiracle; eighth spiracle more dorsal than remainder. Eighth segment dorsally with a transverse row of about eight rather long setæ. Ninth segment dorsally somewhat protruberant rounded and with five pairs of rather long setæ. Anus borne near posterior ventral margin, with a transverse somewhat sinuate cleft and a short median cleft; areas surrounding anus minutely asperate.

Notes.--Descriptions, supposed to be those of Brenthid larvæ were published by Harris and by Motschulsky, but both authors were mistaken in their diagnosis, as has been pointed out by Sharp (1901, 295). Riley described and figured the larva and pupa of *Eupsalis minuta* in 1881. These figures are reproduced by Packard (1890, 70, fig. 20) and by Sharp (l. c. fig. 150), and the description by Felt (1905, 262). According to Riley the larva of *Eupsalis* has 3 pairs of very small three-jointed thoracic legs, the terminal joint being a mere bristle. Heller (1904, 397, 400, t. v. fig. 8-10) describes and figures the larva of *Brenthus lineicollis* from Brazil with 3 pairs of tubercular two-jointed legs, and comments on the occurrence of rudimentary legs in the Curculionidæ.

Muir (1913, 220, fig. 1-3) illustrates the larva and pupa of *Lasiorhynchus barbicornis* from New Zealand stating that the normal larva has very small two-jointed legs, but an abnormal specimen was found with large distinctly six-jointed legs and two pairs of well-defined wing-pads. Dammerman (1919, 74, fig. 26) reproduces an original figure of an undermined brenthid larva from Java, with the legs represented as two pairs of tufts of bristles.

Lameere (1903, 162), forming his opinion largely from the description and figure of the larva of *Eupsalis minuta* Drury given by Riley, disputed the relationship of the Brenthidæ with the Rhyncophora, but as Heller points out he was probably misled by the lack of detail in Riley's description.

Dr. A. G. Boving very kindly gave me a hitherto unpublished plate showing larval details in *Eupsalis minuta*, and this, in common with the species described above, shows the characters common to the Rhyncophora, *e.g.* The curved body form; the much reduced antenna; the continuity of submentum and prothoracic skin, and the presence of a hypopharyngeal bracon. The presence of the leg-like structures (*Warzenbeine* or *Pseudopodien* are term suggested by Heller) is not incompatible with rhyncophorous affinities as many curculionid larvæ show somewhat similar but less evident ambulatory warts. I have seen two larval skins of *Cyphagogus* spp. in which no distinct legs are traceable; the material however is too disintegrated to justify a definite statement.

(b) CEROBATES SEXSULCATUS Motsch.

LARVA.

This larva resembles that of *Cerobates tristriatus* in its general appearance but can be distinguished most easily by the form and size of the thoracic spiracle, which is small and sub-circular in this species whereas in *Cerobates tristriatus* it is large and oval.

Material.—Eight larvæ ex Butea frondosa. Ranipur, Siwaliks, U. P., 18th February 1924. R. R. D. 199 ; B. C. R. 109.

Length.—About 7 mm. in curved position ; width about 1 mm.

Form.—Widely curved, cylindrical, thorax larger than remainder of body.

Colour.—White ; head yellow-brown ; yellowish patches on pronotum prosternum, and mesonotum.

Head capsule.—Subcircular posteriorly ; longer than broad. General structure as in *Cerobates tristriatus.*

Antennæ.—Consisting of basal cushion and a single joint which is slender, tapering slightly and about as long as width of antennal ring ; width of antennal ring about one third that of labrum.

Labrum.—Sub-rectangular, transverse ; anterior margin slightly prominent near middle ; the seta at apex of each epipharyngeal rod rather large. Two pairs of setæ on disc.

Mandibles.—Stout, short, triangular ; about as long as wide. With a blunt apical tooth, a second still blunter tooth just behind the apex and a slight prominence on cutting edge near middle, with two approximate setæ on outer face.

Maxilla.—General structure as in *Cerobates tristriatus.* Setæ on mala about fifteen, the anterior ones flat and blade shaped, the posterior four or five setæ longer and aciculate.

Labium.—Posterior chitinisation of labial stipes distinct and rather strongly chitinised with no median caudad arm. Terminal joint of palp nearly twice as long as that of maxillary palp.

Thorax.—Tergal plate of prothorax more rigid and more distinct than in *Cerobates tristriatus*, otherwise similar ; prosternum yellowish, chitinised. Thoracic spiracle small, sub-circular, length to width as 1·14 to 1·00. Leg structures short, with two apparent joints ; terminal joint bluntly conical and bearing too apical setæ, one longer than the other, and two or three minute setæ near base.

Abdomen.—Spiracles sub-circular, smaller than thoracic spiracle. Ninth segment with four or five pairs of setæ of which two or three pairs are usually fairly long while the remainder are short and less evident. Anal cleft transverse sinuate. Anal lobes somewhat protruberant.

(c) CYPHAGOGUS CORPORAALI KLEINE.

PUPA.

Described from one pupa taken from *Butea frondosa* at Saharanpur, U. P.; R. R. D. 354 ; B. C. R. 188. Adults bred.

Length.—4 mm. width 1 mm.

Colour.—Yellow testaceous with mandibles, parts of antennæ and legs darker brown.

Head.- Bent back under thorax ; antennæ stout curved backwards and upwards apical joint with a few setæ of which two are larger than the others. Head with 2 short setæ on vertex between eyes.

Prothorax.- Completely hiding head from above ; anteriorly on dorsal surface with four distinct setæ arranged in a trapezium. Legs not pressed to body ; hind legs elongate, bent so that claws reached about apex of abdomen. Elytra arising laterally, reaching to about middle of hind femora.

Abdomen. Curved upwards form 1st segment and forming a marked angle with thorax. Abdomen with no strong tubercles or setæ ; segments dorsally with few minute setæ ; penultimate segment with two pairs of fairly stout setæ ; apex with minute hairs.

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GIPC—M—IV-5A (17)—4-3-25—830.

DESCRIPTION OF PLATE IV.

Larva of Cerobates tristriatus Lund.

FIG. 1.—Thoracic skin. *Ms T*, mesothorax ; *Mt T*, metathorax ; P. pleurum ; *Pr T*. prothorax ; Sp. spiracle.

" 2.—Antenna.

" 3.—Maxillæ and labium, ventral surface *ca*, cardo ; *li* ligula ; *lp*, labial palpus ; *MT*, mentum ; *sm*. submentum ; *ma*, mala ; *mp*, maxillary palpus ; *st*, stipes of maxilla ; *stl*, stipes labii.

" 4.—Right mala and maxillary palp, dorsal view.

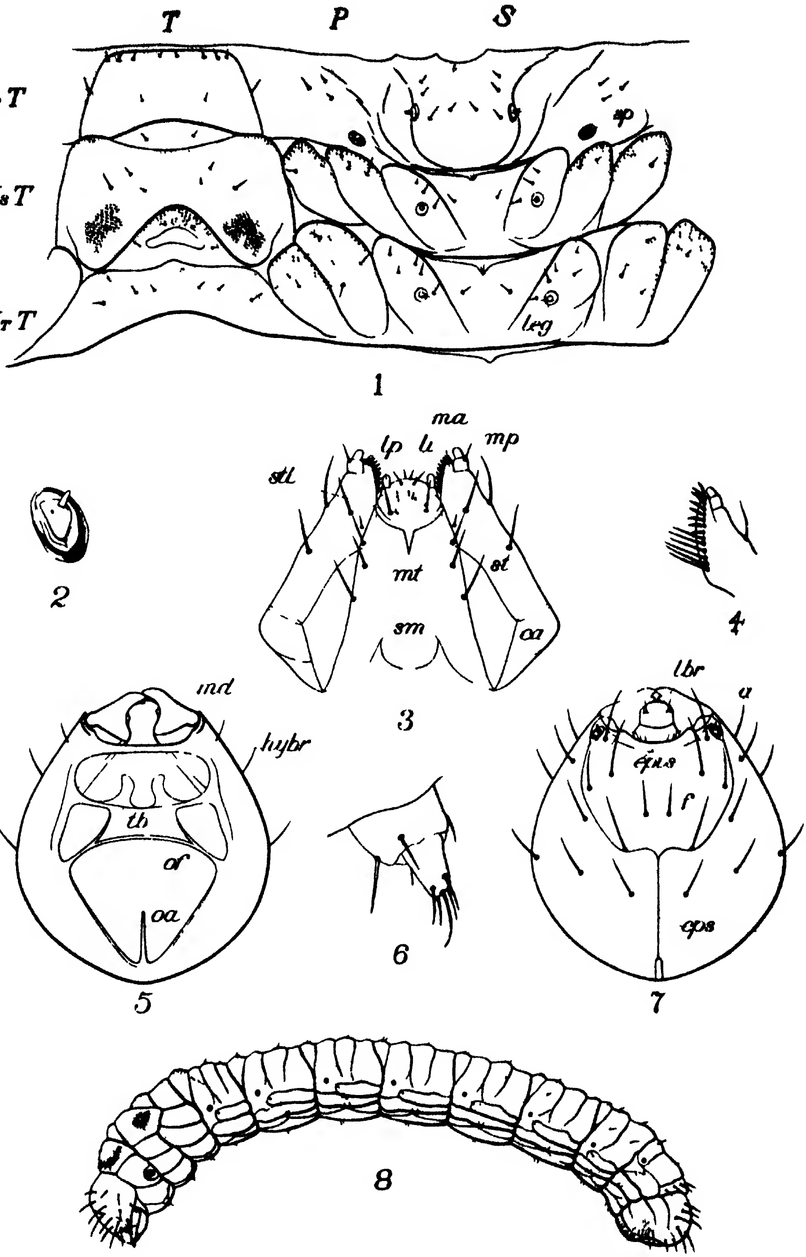
" 5.—Head ventral view (ventral mouth parts removed). *hybr*, hypopharyngeal bracon ; *md* mandible ; *oa* occipital apodeme ; *of* occipital foramen ; *tb* tentorial bridge.

" 6.—Leg structure.

" 7.—Head, dorsal view. *a*, antenna ; *eps* epicranial suture ; *f* frons ; *lbr*, labrum; *epis*, epistoma.

" 8.—Mature larva, lateral view

GIPC-M—IV-5a (17)—12-3-25—800.



LARVA OF CEROBATES TRISTRIATUS LUND.

INDIAN FOREST RECORDS.

Vol. XI. 1924 **Part V.**

THE CONSTITUENTS OF SOME INDIAN ESSENTIAL OILS.

PART XVI.

Note on the rate of Oxidation of *d*-Δ^3-Carene and other Terpenes in the Presence of Catalysts.

MADYAR GOPAL RAO.

It has long been known that Indian Turpentine, obtained from the oleo-resin of *Pinus longifolia* is inferior in quality to the American and French Turpentines, owing to the ease with which it undergoes oxidation, on exposure to the air, with the resultant formation of a resin. As the result of an investigation carried out in this laboratory (Simonsen, Journ. Chem. Soc. Trans. 1920, *107*, 570) it was shown that the rapid deterioration in quality was due to the presence in the oil of a bicyclic terpene to which the name *d*-Δ^3-carene was given.

In view of the great importance of developing the Indian Turpentine Industry it appeared desirable to attempt to improve the quality of the turpentine, and since for economic reasons, it was not possible to eliminate the *d*-Δ^3-carene by fractional distillation it was suggested to the author by Dr. Simonsen that it might prove possible to inhibit the oxidation, or at any rate to greatly retard it, by the addition of some suitable catalyst. Whilst these experiments were in progress, a series of very important papers by Moureu and his collaborators (for references *vide* page 2) on the stabilisation of acraldehyde and the prevention of the oxidation of terpenes and analogous bodies appeared, but in view of the technical importance of the subject. the author considered it desirable to complete his experiments.

Although the inhibiting effect of small quantities of impurities on the rate of oxidation of various substances had long been known, the first systematic investigation of the problem would appear to have been made by Bigelow (Zeit. Phys. Chem. 1893, *26*, 493) who showed that the oxidation of solutions of sodium sulphite was retarded by the addition of certain alcohols such as benzyl alcohol, allyl alcohol and mannitol. He established the fact that secondary alcohols are more efficacious than primary and tertiary alcohols whilst aldehydes and ketones exerted no similar action. Subsequently Tittoff (Zeit. Phys. Chem. 1903, *45*, 541) showed that whereas mannitol inhibited the oxidation of sodium sulphite solutions, copper sulphate acted as a positive catalyst and accelerated the reaction. The effect of organic anti-catalysts on the rate of oxidation of sodium sulphite solutions, was the subject of an extended investigation by Lumiére and Seyewetz (Bull. Soc. Chem. 1905, III, *33*, 444). They showed that hydroquinone, *p*-amino phenol hydrochloride, glycine, *p*-phenylene diamine, catechol, resorcinol and diaminophenol, all acted as anti-catalysts, or as they called them, ' antioxygènes," whereas acetone, formaldehyde and alkalies acted as accelerators.

The investigation of the use of anti-catalysts would appear to have been in abeyance until in 1919 Moureu and Dufraisse (Compt. Rend. 1919, *169*, 621) showed the effect of the addition of small quantities of catalysts on the stabilising of acraldehyde. As the result of a prolonged investigation Moureu and his collaborators * have shown that the most valuable anti-catalysts for the stabilising of aldehydes or for the prevention of the oxidation of readily oxidisable bodies, are hydroquinone, pyrogallol, catechol, resorcinol, 1 : 3 : 4 trihydroxy benzene and α-naphthol while iodine and both inorganic and organic iodine derivatives have proved of value.

The technical importance of this work was recognised by Moureu and has formed the subject of a patent (U. S. 1921, 1436047) whilst Helbronner and Bernstein (Compt. Rend. 1923, *177*, 204) have suggested the incorporation of hydroquinone or tannin to the extent of one to two per cent with rubber latex to preserve it from oxidation. Further Gallet (Compt. Rend. 1923, *176*, 1402) and Sisley (Bull. Soc. Chem.

* The more important references to this work are contained in the following papers—Comp. Rend 1919, *169*, 705, 885, 1068 ; 1920, *170*, 26 ; 1922, *174*, 258, 175, 127; 1923, *176*, 797 ; Bull. Soc. Chem. 1922, IV, *37*, 1152 , Anl. Fis. Quim. 1923, *20* 783 An admirable summary of previous work is given in the paper Bull. Soc. Chem. 1922, IV, *37*, 1152 ; compare also Seyewetz and Sisley, *ibid*, 672.

1923, IV, *33*, 1079) have attempted to correlate the presence of hydroxy groups in the dye molecule with the fastness of dyestuffs to light and oxidation.

Many attempts have been made to afford a theoretical explanation of the observed results of anti-catalysts (Moureu and Dufraisse, Bull. Soc. Chem. 1922, IV, *31*, 1152) (Taylor, Journ. Phys. Chem. 1923, *27*, 322, Journ. Ind. Eng. Chem. 1923, *15*, 902). The consideration of these theories lies outside the scope of this investigation, but it is hoped that experiments now being made in Bangalore by Mr. F. L. Usher may help to elucidate this difficult problem.

The author's attention has been directed mainly to a determination of the rate of oxidation of *d*-α-pinene and *d*-Δ^{3}-carene and of ordinary pure Indian Turpentine, in air and oxygen in the presence and absence of various catalysts, a few experiments having also been made with *d*-Δ^{4}-carene (from *A. Jwarancusa*) and *d*-α-thujene (from *Boswellia serrata*). A full description of the experimental conditions employed will be found on page 5.

It has been found that for the preservation of terpenes pyrogallol is by far the most effective catalyst, hydroquinone inhibited the oxidation for only a short time, whilst alcohols such as mannitol, or ethyl tartarate proved quite ineffective, a similar result being obtained with diphenylamine.

When *d*-α-pinene was allowed to undergo oxidation in oxygen, it was found that complete absorption of the oxygen took place in seventeen days whilst in the presence of 0·001 per cent of pyrogallol, no oxidation took place until after sixty-two days had elapsed. The oxidation then proceeded rapidly and was complete in another sixteen days. With air a similar result was observed; approximately sixty per cent of the oxygen being absorbed in thirty-nine days, whilst in the presence of pyrogallol only twelve per cent oxygen was absorbed in forty-eight days (see Tables I and II and Figs. I and II).

The results obtained with *d*-Δ^{3}-carene were of considerable interest. In the presence of air, during the first twenty-four hours, no less than 19·8 per cent of the available oxygen was absorbed, whilst in eight days complete absorption took place. The addition of 0·001 per cent of resorcin retarded the reaction somewhat, from fifteen to sixteen days were required for complete absorption to take place, whilst the addition of a similar amount of pyrogallol had a marked effect, as after thirty-one days only 24 per cent of the oxygen had been used up (see Table III and Fig. III). With oxygen, the results obtained were somewhat similar, although, as was to be expected, the rate of oxidation was more rapid and even in the presence of pyrogallol, the oxygen had been practically completely absorbed after forty-three days (see Fig. IV).

One feature observed during the experiments was that once the oxidation in the presence of the catalyst had started, it proceeded with great rapidity and the curve had the same form as that of an oxidation proceeding in the absence of a catalyst. A somewhat similar phenomenon was observed by Moureu and Dufraisse (Compt. Rend. 1923, *176*, 797) during their study of the effect of iodine as an anti-catalyst. Since no trace of pyrogallol could be detected in the terpene after the completion of the reaction, it would appear that the phenol undergoes slow oxidation and that it is only after its complete removal that the oxidation of the terpene commences.

The oxidation of a mixture of d-α-pinene (75 per cent) and d-Δ^{3}-carene (25 per cent) with oxygen was next investigated. The speed of the oxidation of d-α-pinene was considerably increased (see Table V and Fig. V), but the addition of pyrogallol had a marked effect, since after 39 days, only 5 per cent of oxygen had been removed. It was expected that ordinary Indian Turpentine (Jallo No. 1) would oxidise at apparently the same rate as this mixture but experiments showed this not to be the case, the rate of oxidation being much more rapid In the absence of a catalyst 97·5 per cent of the oxygen was removed in 4 days. Pyrogallol acted as a powerful inhibitive oxidation not commencing until the sixty-second day and it was not complete until the seventy-sixth day (see Table VII and Fig. VII). As was to be expected the rate of oxidation was slower in air. In the absence of a catalyst it was complete in eight days whilst in the presence of pyrogallol, no oxidation was observed until after the lapse of sixty-one days.

A few experiments were also made with d-Δ^{4}-carene, d-α-thujene and with a mixture of d-α-pinene and d-α-thujene the results of which are given in Tables VIII, IX and X. The speed with which these two terpenes are oxidised is very much less than that observed with d-α-pinene or d-Δ^{3}-carene. It is somewhat suggestive that in both these terpenes the double linkage is conjugated with the cyclopropane ring.

The importance of the use of small amounts of anti-catalysts for various technical purposes has already been recognised by the French investigators of whom previous mention has been made and also by Taylor (*loc cit*) and it would appear to the author possible that the addition of a small percentage of pyrogallol would very much improve the keeping qualities of Indian Turpentine. It has been observed that the addition of pyrogallol causes the development of a slight yellow colour in the oil but it is doubtful if this would be sufficiently marked to lower its commercial value. It is hoped that the publication of this short note may result in further experiments being carried out on a semi-large scale at Bareilly and Jallo.

The author wishes to express his thanks to Dr. Simonsen for suggesting this problem and also for much advice during its progress.

EXPERIMENTAL.

For the determination of the rate of oxidation, the pure terpene which had been prepared by distillation over sodium, and which was kept prior to use in an atmosphere of carbon dioxide, was introduced over mercury into a glass eudiometer tube, the average dimensions of the tube being length 44 centimeters, diameter 1·8 centimeter. Prior to use, the tubes were thoroughly washed with nitric acid, then with chromic acid, and then with distilled water and finally steamed for half an hour. After the introduction of the terpene, the gas, either air or oxygen was allowed to enter the tube and the volume of the gas recorded, simultaneous readings of the volume of turpentine and pressure also being made. The decrease in volume after levelling the mercury inside and outside the tube gave the absorption which had taken place. All the experiments were made in a room in which only diffused light entered and in which the temperature variations had been reduced to a minimum.

The *d*-α-pinene was a very pure specimen free from β-pinene and had been separated from the turpentine from oleo-resin of *P. excelsa*; *d*-Δ^{3}-carene was carefully fractionated from the turpentine from the oleo-resin of *P. longifolia* and boiled with a range of 1°; the *d*-Δ^{4}-carene was a sample which had been prepared from the oil from *Andropogon Jwarancusa*: the *d*-α-thujene was obtained from the oil from *Boswellia serrata* and probably contained a trace of α-pinene.

The results, which are in each case, a mean of two concordant sets of experiments are given in the following tables and curves. All the gas volumes were reduced to N. T. P.

TABLE I.

d-α-Pinene in air.

Day.	A. No Catalyst.	B. With Pyrogallol.
	Percentage of oxygen absorbed.	Percentage of oxygen absorbed.
1	1·3	0·5
4	2·5	"
7	6·7	
9	7·2	
11	11·0	
13	14·0	
15	18·5	
17	23·4	4·2
19	28·1	
21	33·0	
23	37·0	
26	43·0	
29	49·3	6·1
32	52·4	
39	61·2	9·2
48		11·9

TABLE II.

d-α-Pinene in Oxygen.

Day.	A. No Catalyst.	B. With Pyrogallol.
	Percentage of oxygen absorbed.	Percentage of oxygen absorbed.
1	2·4	1·5
2	9·6	
4	24·7	
6	31·9	
8	39·8	
9	47·0	
11	64·5	
12	72·3	
13	79·5	
14	84·9	
17	100·0	
62		5·0
63		10·2
64		15·6
65		20·5
66		28·0
68		42·5
70		60·0
72		72·5
74		84·0
76		94·0

TABLE III.

d-Δ^3-Carene in air (see also Figure I).

Day.	A. No Catalyst.	B. With Resorcin.	C. With Pyrogallol.
	Percentage of oxygen absorbed.	Percentage of oxygen absorbed.	Percentage of oxygen absorbed
1	19·8	10·4	1·4
2	36·0	20·7	4·4
3	47·8	26·8	"
4	63·3	33·3	"
5	75·9	43·5	"
8	100·0	62·2	
9		68·8	
11		78·0	
18		100·0	12·4
31			23·7

TABLE IV.

d-Δ^3-Carene in Oxygen (see also Figure II).

Day.	A. No Catalyst.	B. With Resorcin.	C. With Pyrogallol.
	Percentage of oxygen absorbed.	Percentage of oxygen absorbed.	Percentage of oxygen absorbed.
1	4·8	2·4	1·6
2	20·1	"	"
3	38·1	5·7	
4	51·0	"	
5	60·4	19·0	
6	76·3	33·0	
7	84·3	49·6	2·2
8	89·3	65·6	
9	92·0	77·9	
10	100·0	88·4	
12		100·0	
35			4·6
36			8·8
37			22·2
38			36·9
39			50·2
40			63·6
41			75·7
42			83·6
43			92·1

Table V.

Mixture of d-α-Pinene (75%) and d-Δ^3-Carene (25%) in Oxygen.

Day.	A. No Catalyst.	B With Pyrogallol.
	Percentage of oxygen absorbed.	Percentage of oxygen absorbed.
1	1·3	1·1
4	4·3	"
7	10·5	"
9	15·7	"
11	21·7	
13	27·8	
15	35·0	1·8
17	41·0	
19	47·0	
21	52·4	
23	57·6	
26	65·4	
29	70·2	
32	75·8	1·9
39		5·3

Table VI.

Indian Turpentine No. I in air.

Day.	A. No Catalyst.	B. With Hydroquinone.	C. With Pyrogallol.
	Percentage of oxygen absorbed.	Percentage of oxygen absorbed.	Percentage of oxygen absorbed.
1	10·7	2·9	
2	25·4	"	
3	49·7		
4	64·7		
5	85·5		
8	97·5		
24		4·4	
26		18·2	
28		33·0	
30		47·3	
31		53·1	
32		59·0	
34		70·6	
36		95·0	
60			7·0
62			18·0
63			27·4
64			37·8
65			48·0
66			57·9
67			68·3
70			92·0

TABLE VII.

Indian Turpentine No. I in Oxygen.

Day.	A. No Catalyst.	B. With Hydro-quinone.	C. With Pyro-gallol.
	Percentage of oxygen absorbed.	Percentage of oxygen absorbed.	Percentage of oxygen absorbed.
1	15·8	0·7	0·5
2	53·8		
3	82·6		
4	97·0		
5	100·0	2·3	
13		3·6	
18		11·0	
20		26·6	
21		61·6	
22		87·0	
24		100·0	
36			2·3
48			4·1
62			10·6
64			16·0
66			26·0
67			33·0
70			56·0
72			68·6
74			80·0
76			92·0

TABLE VIII.

d-Δ^{4}-Carene in Oxygen.

Day.	No Catalyst.
	Percentage of oxygen absorbed.
1	6·4
3	9·3
4	20·8
7	49·0
8	57·1
9	65·5
10	70·8
12	84·0
14	96·4

TABLE IX.

d-α-Thujene in Oxygen.

Day.	A. No Catalyst.	B. With Pyrogallol.
	Percentage of oxygen absorbed.	Percentage of oxygen absorbed.
1	0·9	1·1
28	2·8	"
37	9 9	"
41	24·3	"
45	28·6	"
58	43·6	"
77	64·0	"
100	85·5	"
		No absorption after 5 months.

TABLE X.

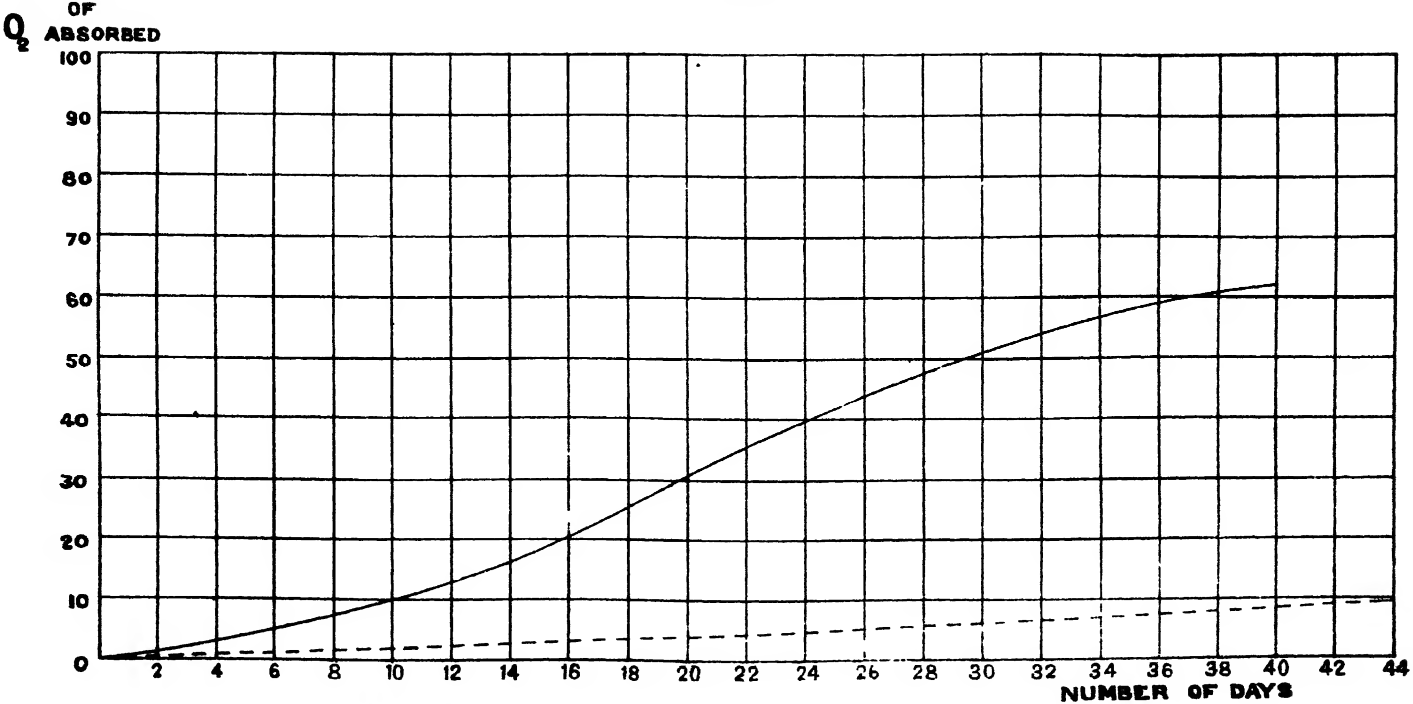
d-α-Pinene (50%) and d-α-Thujene (50%) in Oxygen.

Day.	
	Percentage of oxygen absorbed.
1	0 6
5	5·5
7	6·6
11	9·8
16	16·1
21	22·8
28	30·2
37	39·2
41	52·2
45	59·0
58	80·5
77	92·0

The author wishes to thank Mr. P. H. Guest, Manager, Turpentine Factory, Jallo, for supplying the No. 1 Turpentine used in these experiments,

FOREST RESEARCH INSTITUTE AND COLLEGE,
DEHRA DUN. *21st July, 1924.*

Fig I

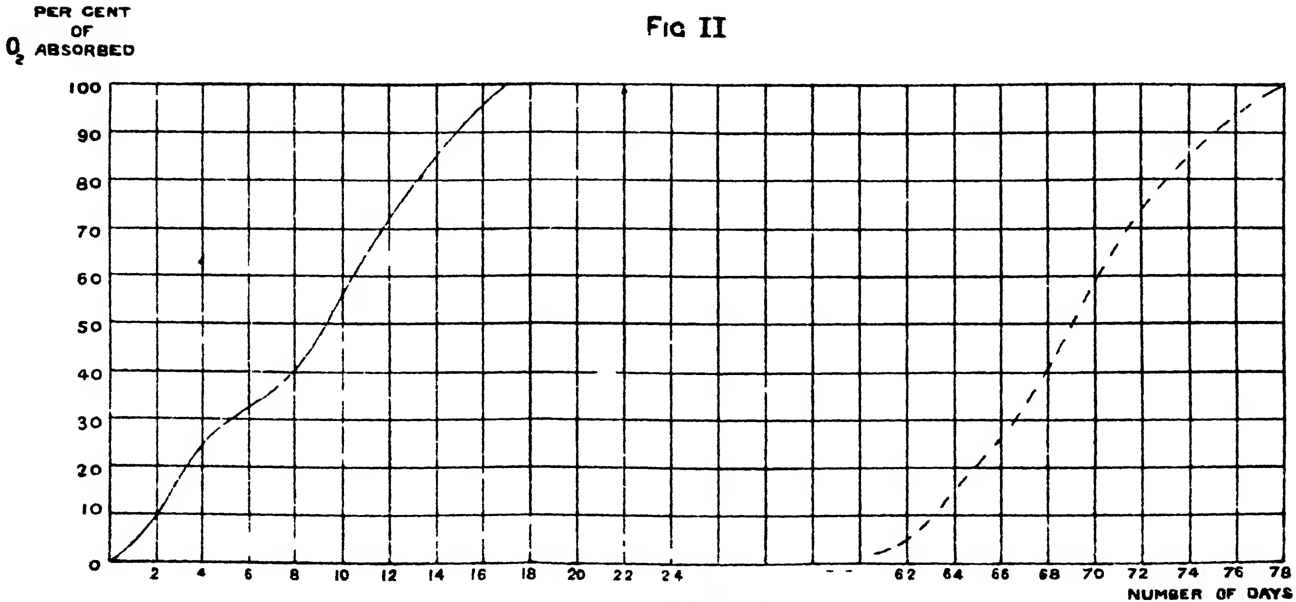


OXIDATION OF $d\alpha$ PINENE IN AIR

α PINENE WITH NO CATALYST ————

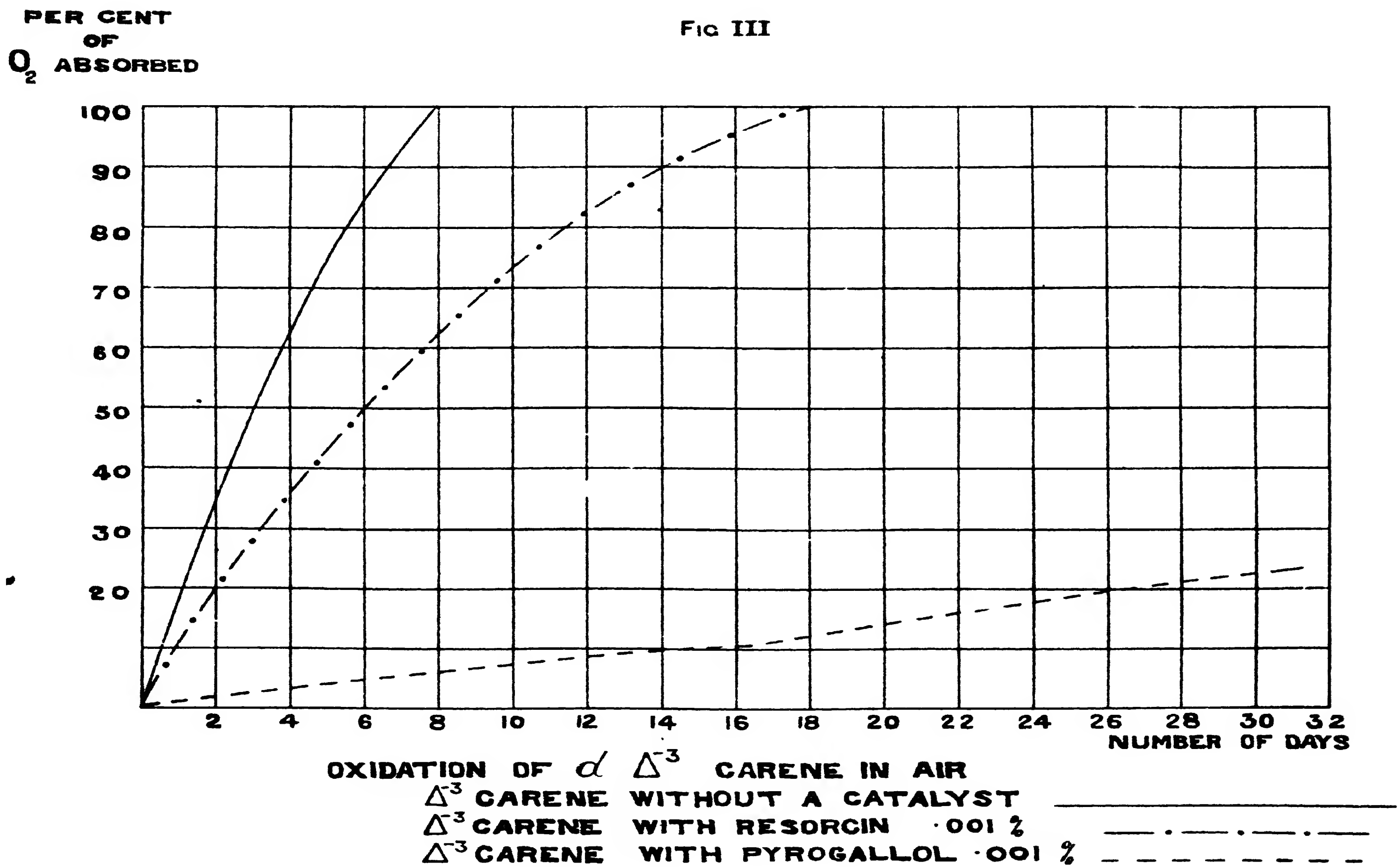
α PINENE + PYROGALLOL ·001 % - - - - - - -

Fig II



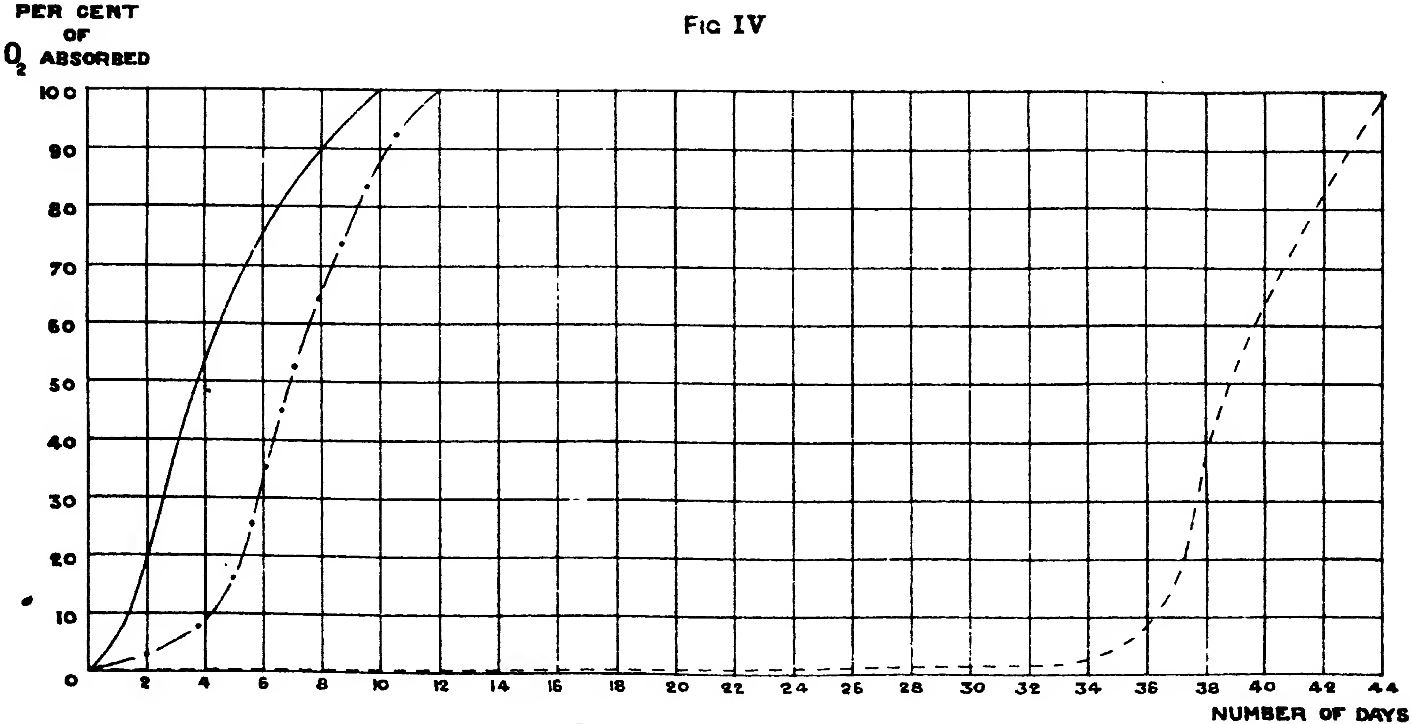
OXIDATION OF d α PINENE IN OXYGEN
α PINENE WITHOUT A CATALYST ————
α PINENE + PYROGALLOL 001 % – – – – – –

Fig III



OXIDATION OF d Δ^{-3} CARENE IN AIR

Fig IV



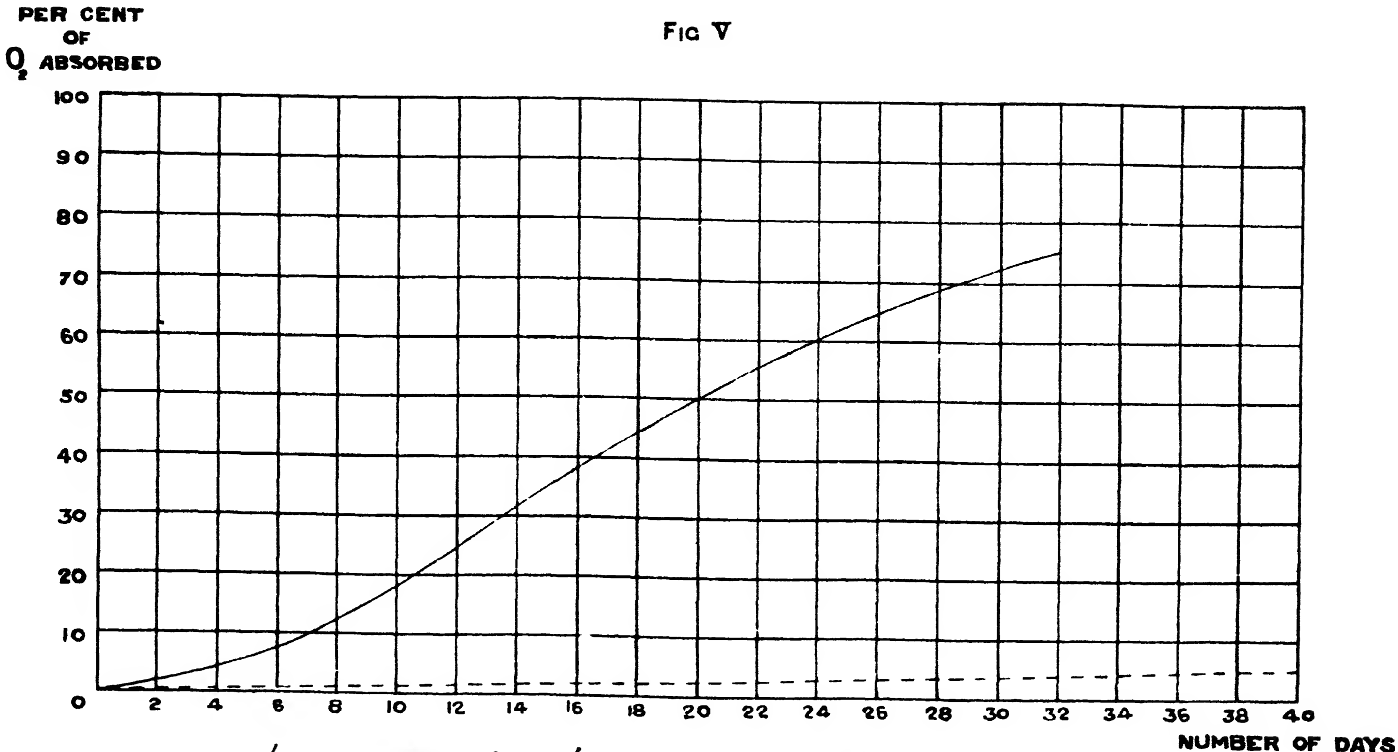
OXIDATION OF $d\ \Delta^{3}$ CARENE IN OXYGEN

Δ^{3} CARENE WITHOUT A CATALYST ————————

Δ^{3} CARENE WITH RESORCIN ·001 % —·—·—·—·—

Δ^{3} CARENE WITH PYROGALLOL ·001 % - - - - - - - -

Fig V



$d\alpha$ PINENE 75 % + d Δ^3 CARENE 25 % IN OXYGEN

MIXTURE WITHOUT A CATALYST ————————

MIXTURE WITH PYROGALLOL ·001 % - - - - - - - - -

Fig VI

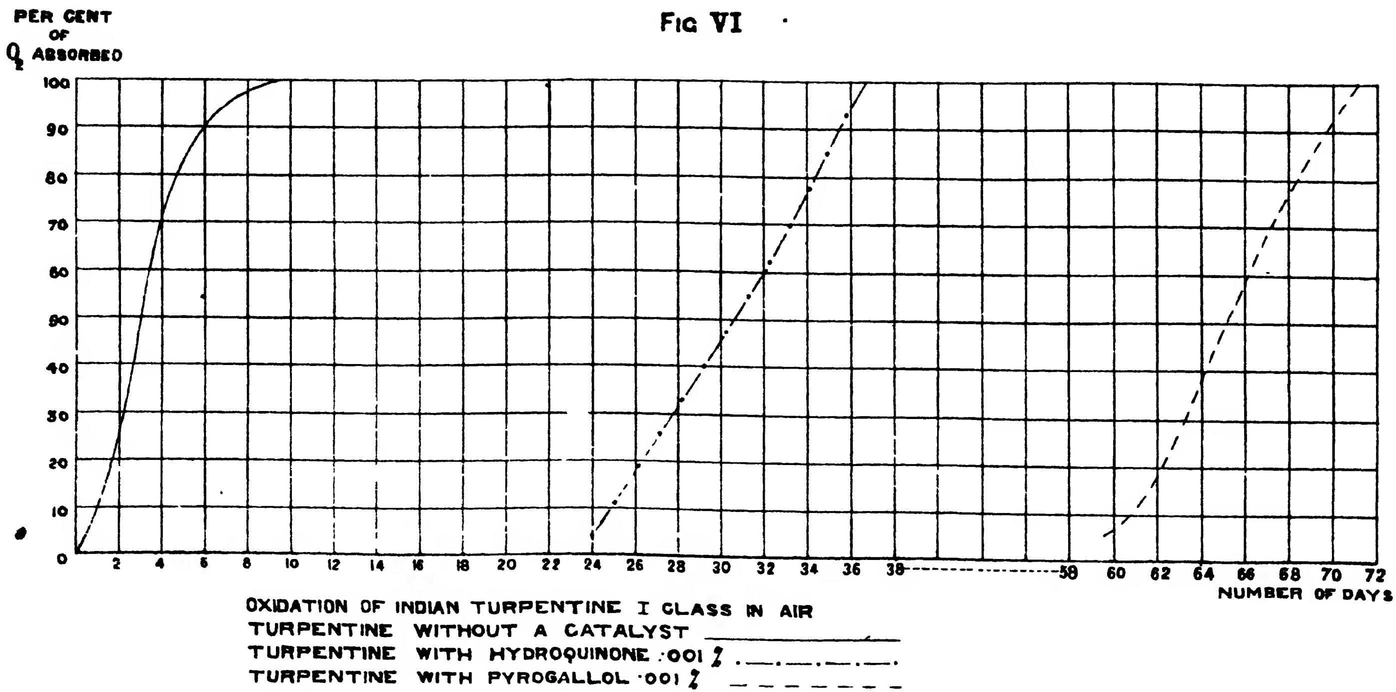
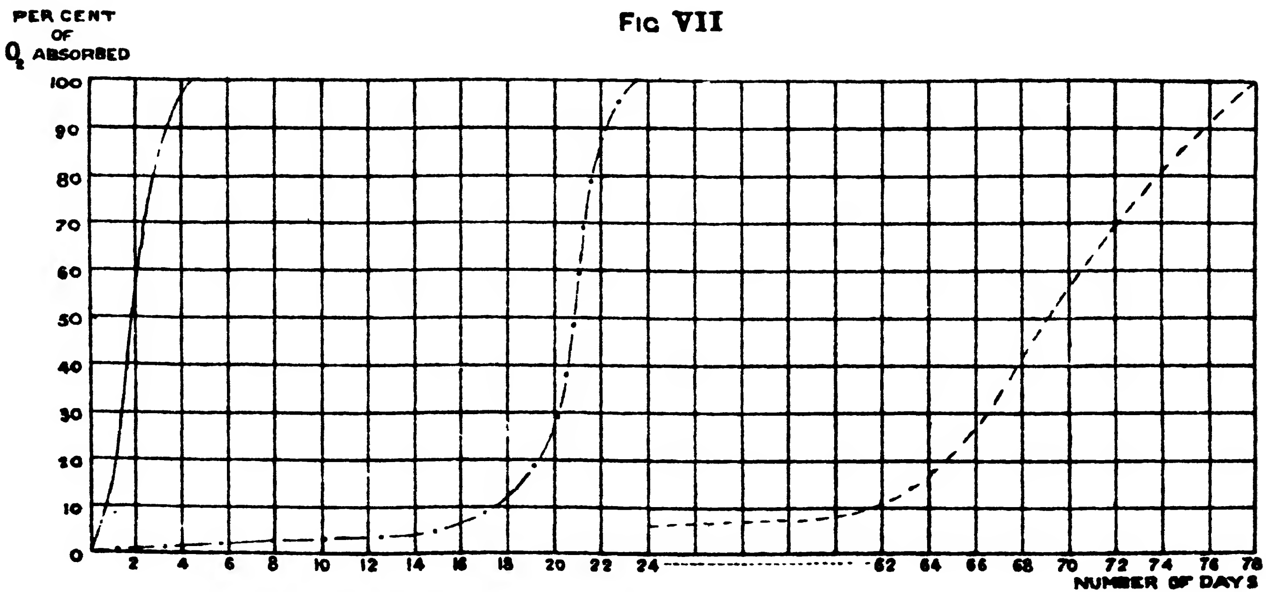

PER CENT
OF
O_2 ABSORBED
100
90
80
70
60
50
40
30
20
10
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
58
60
62
64
66
68
70
72
NUMBER OF DAYS
OXIDATION OF INDIAN TURPENTINE I CLASS IN AIR
TURPENTINE WITHOUT A CATALYST
TURPENTINE WITH HYDROQUINONE ·001 %
TURPENTINE WITH PYROGALLOL ·001 %

Fig VII



OXIDATION OF INDIAN TURPENTINE I CLASS IN OXYGEN
TURPENTINE WITHOUT A CATALYST ————
TURPENTINE WITH HYDROQUINONE ·001 % —·—·—·—
TURPENTINE WITH PYROGALLOL ·001 % - - - - - - -

INDIAN FOREST RECORDS.

Vol. XI] 1924. [Part VI

THE CONSTITUENTS OF SOME INDIAN ESSENTIAL OILS.

PART XVII.

Abietic Acid from the Rosin of *Pinus longifolia*, Roxb

(Preliminary Note.)

BY

MADYAR GOPAL RAU AND JOHN LIONEL SIMONSEN.

As a preliminary step to other experiments which are in progress on the rosin from the oleo-resin of *Pinus longifolia* Roxb., it has appeared desirable, in the first instance, to establish the identity of the principal acid constituent of this resin.

In spite of the very large number of investigations which have been carried out on the crystalline acids present in the rosins derived from the oleo-resins of the various species of *Pinus*, it is only in recent years that some degree of order has been evolved in this difficult field of research.*

So far as our present knowledge extends the rosin acids would appear to belong to two distinct groups (*a*) the abietic acid group, the members of which, when dehydrogenated with sulphur, yield retene and (*b*) a

* The more important recent work on the constitution of abietic acid is contained in the following papers :—

Aschan, Ber. 1921, *54*, 867, 1922, *55*, 2944, Annalen, 1921, *424*, 117, Aschan and Ekholum, Annalen, 1921, *424*, 150; Virtanen, Annalen, 1921, *424*, 150; Ruzicka and Meyer, Helv. Chim. Acta, 1922, *5*, 315, 581, Ruzicka and Balas, *ibid*, 1923, *6*, 677, Ruzicka and Schinz, *ibid*, 1923, *6*, 662, 833, Dupont and Uzac, Bull. Soc. Chim. 1924, (IV), *35*, 394.

second group, of which pimaric acid is the chief representative, which on dehydrogenation yields a hydrocarbon $C_{16}H_{14}$ probably a dimethyl phenanthrene.

One of the main difficulties in the study of the rosin acids lies in the fact that the melting points and the rotatory powers of the acids have been found to be considerably influenced by the method adopted in their purification, a point to which attention has already been directed by Ruzicka and his collaborators. The preparation of characteristic derivatives also affords very considerable difficulty since like the rosin acids themselves they tend to undergo change during purification.

As the result of our experiments we have definitely established the nature of the chief acid present in the rosin derived from *P. longifolia* and have shown it to be abietic acid identical in all respects with the acid present in the rosin from *P. palustris*. Both acids when purified by Steele's method (Journ., Am. Chem. Soc., 1922, *44*, 1333) were found to melt at 168-169° and to be crystallographically identical (see pages 4 and 5). They only differed slightly in their rotatory power.

We have also been able to confirm the identity of the two acids by the preparation of a number of derivatives some of which would appear to be new. The new derivatives, the preparation and purification of which are described in detail in the experimental part of this paper, comprise a *dihydrochloride* melting at 205°, a *monohydrochloride* melting at 197°, a *monohydroxy* acid melting at 230° and a dimolecular *hydrochloride* decomposing at about 310°. The purification of the halogen derivatives afforded at first very considerable difficulty until it was observed that these substances underwent decomposition when recrystallised from solvents which contained either water or alcohol. If due precautions are taken to eliminate traces of water and alcohol from the solvents used in their purification both the dihydrochloride and monohydrochloride were obtained as beautifully crystalline substances and are eminently suitable for the characterisation of abietic acid.

The dimolecular hydrochloride referred to above has the formula $C_{40}H_{59}O_3Cl$ and would appear to contain two molecules of abietic acid. Owing to the extremely small quantity which has so far been obtained it has not been possible to examine it in detail.

Although the dihydrochloride showed a great tendency to lose two molecules of hydrogen chloride with regeneration of abietic acid, it was found to undergo a somewhat unusual reaction when boiled with a solution of sodium bicarbonate being converted into an unsaturated monohydroxy acid. *Monohydroxy abietic acid*, like abietic acid, is a very weak acid being precipitated from an alkaline solution by carbon dioxide,

it was, however, soluble in sodium carbonate solution. It formed a crystalline *methyl* ester which melted at 110°. This interesting acid is being further investigated and it is hoped that it may prove of value in elucidating the constitution of abietic acid since preliminary experiments have shown that it yields crystalline products on oxidation with potassium permanganate. In the meantime a discussion of the constitution of abietic acid and also of the results of Knecht and his collaborators (Journ. Soc. Dyers and Cols. 1919, *35*, 148, 1923, *39*, 338) is postponed.

For convenience of reference the various crystalline derivatives of abietic acid prepared by previous investigators and the authors is given in the following table :-

Derivative.	Ruzicka and Meyer.	Aschan and Virtanen.	R. and S.
Acid	M.P. 158° . $[\alpha]_D$—68·5° (in alcohol) also isomeric acids.	M.P. 182° . $[\alpha]_D$—30·7° (in alcohol).	M.P. 168—169°. $[\alpha]_D$—95° (in alcohol) no isomerides
Dibromoacid	..	M.P. 107-110° .	M.P 108°
Dihydrobromide . . .	M.P about 178°	M.P. 188-192° .	M.P. 189°.
Monohydroiodide . . .	..	M.P. 191-193° .	M.P. 191°.
Dihydrochloride . . .	..	..	M.P. 205°.
Monohydrochloride . .	..	..	M.P. 197°.
Hydrochloride (dimolecular) .	..	..	M.P 310° decomp.
Nitrosochloride . . .	..	M. P. 144-145°	M.P. 144°.
Nitrosite	..	softens 75° . melts 120-130°	M.P. 90-94°.
Nitrosate	..	M.P. 72-73° .	..
Monohydroxy acid . . .	..	..	M P. 230° ($[\alpha]_D \pm 0°$).
Methyl ester of monohydroxy acid.	..	..	M.P. 110°.

The authors wish to express their thanks to Mr. P. H. Guest of the Jallo Turpentine Factory for supplying them with large quantities of high grade colophony and to Professor L. E. Wise of Syracuse University and Dr. Schorger for a sample of the colophony from *P. palustris* which enabled them to establish the identity of the abietic acid.

EXPERIMENTAL.

Isolation and Purification of Abietic Acid.

In order to determine whether the abietic acid from Indian colophony was a homogeneous substance it was extracted from the crude rosin by various processes but since the acid obtained showed in each case the same rotatory power and melting point it is unnecessary to give the details. For the preparation of the crystalline acid in quantity Steele's method (Am. Chem. Soc., 1922, *44*, 1333) was found to be the most convenient.

The crude crystalline acid, which was somewhat yellow in colour, was purified by repeated crystallisation from the minimum quantity of methyl alcohol until the rotatory was constant, the acid being allowed to crystallise in an atmosphere of carbon dioxide. For analysis it was further purified through the sodium salt when it was found to melt at 168-169° and in five per cent. ethyl alcohol solution $[\alpha]_D = 95{\cdot}3°$ was observed.

0·1192 gave 0·3452 CO_2 and 0·1054 H_2O C=79·0 H=9·8.

$C_{20}H_{30}O_2$ requires C=79·4 H=10·0 per cent.

A molecular weight determination in acetic acid gave a mean value of 304, the calculated value for an acid of the formula $C_{20}H_{30}O_2$ being 302.

As was observed by Virtanen (loc. cit.) in the case of pinabietic acid the rotatory power was found to show marked variation in different solvents.

Solvent.	Strength of solution.	$[\alpha]D$.
Ethyl alcohol	5·0 per cent.	—95·5°
Methyl alcohol	5·0 ,,	—82·5°
Acetic acid	4·2 ,,	—69·4°
Acetone	5·0 ,,	—82·5°
Ethyl acetate	4·0 ,,	—86·7°
Chloroform	5·3 ,,	—58·4°
Benzene	5·2 ,,	—7·5°

Specimens of the abietic acids from the rosins of *P. longifolia* and *P. palustris* were kindly crystallographically examined by Mr. G. M. Bennett in Professor C. S. Gibson's laboratory, Guy's Hospital Chemical Laboratory, London. The following report was furnished:—

" *Acid from P. palustris.*—The substance crystallises well from warm glacial acetic acid, the solution depositing small plates of a rectangular

shape with a triangular termination at one end only the angle at the apex being 90°. These plates show a straight extinction. In convergent polarised light there is visible part of a system of rings belonging to an optic axis emerging just outside the field of view, the dark brushes crossing the field when it is rotated.

Acid from P. longifolia.—The substance crystallised in the same way from acetic acid and the plates deposited showed the above effects in every respect.

It is clear that these substances are crystallographically identical. The substance gives biaxial crystals belonging to either the orthorhombic or the monclinic systems."

There can, therefore, be no doubt that these two acids are chemically identical and this was confirmed by the preparation of their derivatives. The acid from *P. palustris* was observed to have a somewhat lower rotation than the acid from *P. longifolia*, the observed value in five per cent ethyl alcoholic solution being $[\alpha]_D - 87{\cdot}8°$.

Nitrosochloride of abietic acid.- This substance was readily prepared by the method described by Aschan (Ber. 1922, *55*, 2944). After crystallisation from a mixture of chloroform and light petroleum it melted at 144°.

0·2861 gave 0·1103 AgCl Cl - 9·5.

$C_{20}H_{30}O_3$ NCl requires Cl 9·6 per cent.

Nitrosite of abietic acid.- The nitrosite (compare Aschan, loc. cit.) was precipitated from a benzene solution on addition of light petroleum as a microcrystalline powder which melted at about 90-94°. The substance was apparently not quite pure, but it resisted all attempts at further purification tending to separate from solvents as a viscid resin.

0·2135 gave 16·1 cc. of N_2 at 28° and 702 mm. N=7·6.

$C_{20}H_{30}O_5N_2$ requires N -7·4 per cent.

Dibromoabietic acid.— The bromo acid prepared by Virtanen's method (Annalen, 1921, *424*, 195) crystallised from hexane in small yellowish needles which decomposed at 108°.

0·1335 gave 0·1078 AgBr Br=34·4.

$C_{20}H_{30}O_2Br_2$ requires Br=34·6 per cent.

The action of Hydrogen Chloride on Abietic Acid.

The interaction of hydrogen chloride and abietic acid was found to proceed most satisfactorily under the following conditions. The acid was dissolved in seven and a half times its weight of acetic acid and after cooling in ice the mixture was saturated with hydrogen chloride. The reaction vessel was sealed and allowed to stand at the ordinary

temperature. After two or three days the separation of the dihydrochloride commenced and was practically complete in about a week. After the lapse of a fortnight the reaction mixture was cooled with ice, the crystalline solid collected at the pump, washed with acetic acid and dried on porous porcelain in a vacuum desiccator. The yield was found to vary considerably with the prevailing laboratory temperature, at 25° it was 55 per cent. and at 18° 33 per cent.

The crude hydrochloride, which was a mixture of at least two substances, was purified by repeated trituration with cold benzene when the *dihydrochloride*, which was very sparingly soluble in this solvent remained undissolved, the fraction (A) soluble in benzene was reserved for later examination (see below). The dihydrochloride, which decomposed at 191-193°, was purified by crystallisation from either benzene or ethyl acetate when it was obtained in fine glistening needles which melted at 205°.*

0·112 gave 0·2633 CO_2 and 0·0848 H_2O C=64·1 H=8·3.

0·1954 gave 0·146 AgCl Cl=18·5.

$C_{20}H_{32}O_2Cl_2$ requires C-64·0 H=8·5 Cl=18·9 per cent.

A molecular weight determination by Rast's method gave a value of 370 agreeing well with the calculated value of 375.

The fraction (A) (see above) which was soluble in cold benzene, remained on removal of the solvent as a pasty mass. It was repeatedly recrystallised from ethyl acetate in which solvent it was found to be much less soluble than the dihydrochloride and it was ultimately obtained in fan shaped aggregates of needles which decomposed at about 310°. The *monohydrochloride*, which apparently contained two molecules of abietic acid, was very readily soluble in benzene, and toluene, somewhat sparingly so in hot acetic acid and ethyl acetate. Owing to the small quantity of material available it has not as yet been examined in detail.

0·1063 gave 0·2986 CO_2 and 0·0934 H_2O C=76·6 H=9·7.

0·24 gave 0·0512 AgCl Cl-5·6.

$C_{40}H_{59}O_3Cl$ requires C-77·1 H=9·5 Cl=5·7 per cent.

A molecular weight determination by Rast's method gave values of 615 and 617 whilst a substance of the formula $C_{40}H_{59}O_3Cl$ requires M=622·5.

Monohydrochloride of abietic acid.—For the preparation of the *monohydrochloride of abietic acid* the following method was found to yield the best results. The finely divided dihydrochloride (3 grammes) was mixed with methyl alcohol (60 cc.) and heated on the water bath in a reflux

(* In recrystallising the dihydrochloride it was found essential to use perfectly pure dry solvents since the acid was found to be rapidly decomposed when warmed with ethyl or methyl alcohol, acetone or acetic acid.)

apparatus until a clear solution was obtained approximately thirty minutes being required. The reaction mixture was cooled in ice when a portion of the monohydrochloride crystallised. This was collected (yield 0·5 gramme) and the filtrate allowed to evaporate in vacuo when a further quantity of the hydrochloride was obtained mixed with a little halogen free acid, the amount of the latter substance being increased if the initial heating is too prolonged.

The *monohydrochloride* of abietic acid was purified by crystallisation from the minimum quantity of ethyl acetate from which solvent it separated in massive cubes which melted at 197°. It was found to be readily soluble in chloroform, carbon tetrachloride, hot benzene and ethyl acetate, more sparingly so in the cold. In boiling methyl and ethyl alcohols and acetic acid it dissolved with simultaneous partial decomposition into halogen free acids.

0·106 gave 0·2751 CO_2 and 0·0884 H_2O C=70·7 H=9·3.

0·2078 gave 0·0864 AgCl Cl=10·3.

$C_{20}H_{31}O_2Cl$ requires C=70·9 H=9·2 Cl=10·4 per cent.

The monohydrochloride was also formed when the dihydrochloride was treated with an alcoholic solution of potassium acetate, sodium ethylate, pyridine or potassium hydroxide in alcoholic solution, the product was, however, less pure than when methyl alcohol was used. On treatment with hydrogen chloride it was reconverted into the dihydrochloride. When boiled with a dilute solution of sodium carbonate the monohydrochloride was converted into abietic acid which was identified by the method of mixed melting point and by analysis. (Found C=79·0 H=10·0, calc. C=79·4 H=10·0 per cent.)

Action of Sodium Bicarbonate on the Dihydrochloride of Abietic Acid. Monohydroxy abietic Acid.

For the preparation of this interesting acid the following method has proved to be the most convenient.

The finely powdered dihydrochloride (10 grammes) was mixed with a solution of sodium bicarbonate (300 cc. $NaHCO_3$ 7·5 grammes) and heated in an oil bath at 120° in a reflux apparatus a rapid stream of carbon dioxide being passed through the solution. After two hours the liquid, which still contained a little unattacked dihydrochloride in suspension, was filtered and allowed to cool in a current of carbon dioxide when a caseous white precipitate separated. This was collected, thoroughly washed with cold water and dried in a vacuum desiccator over sulphuric acid.* (Yield 7 grammes.)

(* A small further amount of the hydroxy acid (0·5 gramme) was obtained from the filtrate after acidification and extraction with ether.)

The crude acid was triturated with a little cold acetone which removed impure abietic acid and then recrystallised from the same solvent from the hot solution of which it separated in minute prisms melting at 230°. In acetone solution it was found to be optically inactive. For analysis it was dried over phosphorus pentoxide.

0·102 gave 0·2806 CO_2 and 0·0909 H_2O C=75·0 H=9·9.

$C_{20}H_{32}O_3$ requires C=74·7 H=9·7 per cent.

The *silver* salt prepared in the usual manner was obtained as a white amorphous powder which differed from the silver salt of abietic acid in being sparingly soluble in benzene.

0·4448 gave 0·1108 Ag Ag=24·9.

$C_{20}H_{31}O_3Ag$ requires Ag=25·3 per cent.

The *methyl* ester prepared from the silver salt by treatment with methyl iodide in benzene crystallised from methyl alcohol in radiating needles which melted at 110°.

0·103 gave 0·2833 CO_2 and 0·0912 H_2O C=75·0 H=9·8.

$C_{21}H_{34}O_3$ requires C=75·4 H=10·1 per cent.

FOREST RESEARCH INSTITUTE,
DEHRA DUN.

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INDIAN FOREST RECORDS

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Volume Tables for (*Tectona grandis*) Teak and (*Shorea robusta*) *Sal* for the Central Provinces

BY

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Silviculturist, Central Provinces.

1. These tables are based on measurements, taken by the writer in the field season of 1924, of some 2,000 teak and 1,100 *sal* trees. The teak data were drawn from localities of Qualities I, II, III, and IV, in the divisions of South Chanda (Allapilli) Melghat, Hoshangabad, and Nagpur-Wardha: the *sal* from Qualities I, II, and III, in the divisions of South Raipur, Balaghat, and South Mandla (Banjar). Quality IV *sal* was not taken as it is of rare occurrence in the province. A local volume table for the small Pachmarhi municipal *sal* forest would give the best results for Quality IV *sal*.

The qualities referred to are those standardised for the province *viz.*:—

Quality I	Over 90′	(Maximum height of mature trees.)
" II	71′—90′	Do.
" III . . .	51′—70′	Do.
" IV	Under 50′	Do.

2. Field work consisted of obtaining for each tree the following measurements:—

(*a*) Girth over bark (in inches) at 4½′.

(*b*) Total height (in feet).

(*c*) Girth over bark (in inches) of useful log or pole.

(*d*) Length (in feet) of useful log or pole.

A rough allocation to locality-qualities of the sites from which the trees were taken was made at the time of measuring. This was intended primarily to be a check ensuring a reasonably even distribution of girth classes and locality-qualities among the trees selected.

3. Of the measured trees, 300 teak and 310 *sal* were also measured in detail for true Standard* volume. From these data it was hoped to establish a curve showing the relation $\frac{\text{C. P. exploitable volume}}{\text{True volume}}$ for different girth classes, and to read off from such a curve the true volume values corresponding to the exploitable volume values to be given by the main volume table information. It was, however, found that there were insufficient trees of the larger girth classes, and the establishment of the relation indicated must await further field work.

Meanwhile standard volume figures (for *sal* at least), can be obtained from Howard's "General Volume Tables for *Sal*" (Ind. For. Records, Vol. X, Part VI, 1924), should they be wanted for comparison, or for working out a relation between standard and C. P. exploitable volume

4. The data for each species were arranged in 3″ girth classes from 6″ girth up to 24″ girth, and in 6″ girth classes from 25″ girth upwards Figures were arranged for each of these girth classes in the following height classes:—

(1) 11′—30′,

(2) 31′—50′,

(3) 51′—70′,

(4) 71′—90′,

(5) 91′—110′.

Average figures were then calculated for:—

(*a*) Girth at 4½′,

(*b*) Girth at half useful log or pole,

(*c*) Length of useful log or pole,

(*d*) Total height.

For each average girth at half useful log or pole, and each corresponding average length of useful log or pole, an average quarter girth volume (including bark) was obtained. The average girths were converted to diameters for convenience in plotting, and the values $\frac{\text{Average volume}}{\text{Average diameter}}$ plotted. The number of trees represented by each point was noted and preliminary curves were drawn by height classes through the points. From these curves the volumes corresponding to the exact mid-girths of each girth class were read off and replotted over the average heights already calculated for each girth class. A separate

* The standard definition for timber is above 8″ diameter (over bark) at the thin end. Timber is measured actually under bark. Smallwood is anything not timber down to 2″ diameter (over bark) and is actually measured over bark.

curve for each girth class was thus established from which the final data for $\frac{\text{Volume}}{\text{Exact mid girth}}$ by height classes were read off and plotted These final curves are reproduced. (Curves 1 to 4.)

5. The use of these volume curves by separate and definite height classes gives the most accurate set of volume figures, but in practice demands the noting of the total height of each tree at the time of enumeration. The labour involved, however, is not so great as might appear—with practice height estimation can be carried out with remarkable speed and accuracy.

6. For the convenience of those who prefer to allot areas to qualities and to apply a table for a given locality-quality varying only by girth, the writer, in the field, allotted areas to qualities, and has worked out volume tables for each locality-quality eliminating the height variation.

The quality curves drawn were arrived at first by plotting actual average heights over actual average diameters for each locality-quality. Curves were drawn from which the final quality-volume curve data were taken. The data were read off by taking the average heights corresponding to exact mid-girths of classes from the curve, and then obtaining for the former the corresponding volumes from the height class volume curves already established.

The quality curves so obtained hence depend on individual judgment in allotting localities to qualities in the field and then selecting individual trees of true average height for their girth in those qualities, including dominant, dominated, and suppressed trees in their existing proportions.

7. The use of the tables by an officer in the field making an enumeration can thus be detailed as follows.

To obtain the most accurate results, trees should be measured at 4½′ and individual heights taken. The average girth and average height of each class should be calculated and the appropriate volume for each girth-class read off from the volume curves arranged by height classes.

Should a local volume table be wanted it can readily be made by finding the average heights for each girth and interpolating this on the volume curves arranged by height classes. A smooth curve through the interpolated points will give the required local table of volumes corresponding to girths. Reference is invited to Howard's General Volume Tables for *Sal* (Ind. For. Records, Vol. X, Part VI, 1924) in which this method has been adequately detailed already.

8. The main difficulty in the preparation of a general volume table for the province lay in the fact that in different divisions there were different ideas as to what constituted useful timber. It was found naturally that girth and length limits varied with distance from markets, facilities for extraction, and general intensity of demand.

The figures given do not profess to give more than a general average, and only claim to approach accuracy for large numbers of trees. Their chief value, it is hoped, will be in providing a basis for the production of local divisional or even range volume tables. Factors for rottenness, etc., must be worked out locally and this being done, we may in the Central Provinces be able to arrive at reasonably correct figures for the useful volume of our coupes, and enable auctions to proceed on a more business-like basis by eliminating the present speculative element.

9. The curves given illustrate the enormous rise in volume (and consequently value) corresponding to rise in quality of a locality. It is known that with proper tending and conservancy the quality can be steadily and cumulatively improved. In many cases quality II may be converted to quality I, quality III to quality II, etc. The writer has actually seen cases of teak coppice shoots, 11 years old of greater total height than adjacent mature stems on the same original stump and his opinion based on observation of woods in all the types obtaining in the province is that there is no reason why proper tending, thinning, and general protection should not improve the majority of our forests at least one quality.

A further point is that the effect of proper treatment is to produce a greater length of useful bole in a given height class so that the present volumes for, *e.g.*, height class 51′—70′ may be attained by the height class 31′—50′ of the future.

Expressed in terms of revenue for the province the increase would be enormous.

10. It will be noticed that a distinct falling off occurs at about 7′ girth on the curves for teak This falling off does not occur in the *sal* and the explanation offered is that the best of our larger teak trees were hacked out in the past and that we have only inferior individuals of the very large sizes left in the province. The *sal* curves show no falling off and the reason appears similarly to be that large *sal* timber was left alone more, and not entirely destroyed prior to the reservation of the C. P. forests. *Sal* has become generally exploitable more recently than teak and happens to occur in the more remote localities.

11. As regards the timber and other limits taken in the field in the course of the collection of the figures on which these tables are based; the local conception of what was exploitable was accepted in each case, and it was fortunately found not to vary so much as to vitiate results. The resultant mean obtained may be somewhat high for some divisions and somewhat low for others, but these objections will tend to be eliminated with the more complete and detailed working which we anticipate and which, it is hoped, will equalise intensity of working throughout the province.

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TABLE I.—*Teak.*

Volume of timber in the round including bark (local C. P. [illegible] height classes to the nearest ½ cubic foot.

Girth class.	HEIGHT CLASS (FEET).				
	11'—30'	31'—50'	51'—70'	71'—90'	91'—110'
Over 7"—10"					
,, 10"—13"	½	1	1½		..
,, 13"—16"	1	1½	1½		
,, 16"—19"	1	2	3½		
,, 19"—22"	1	2½	4	.	...
,, 22"—25"	1½	3	5	7	
,, 25"—31"	1½	4	7	10	..
,, 31"—37"	2	5½	10	14½	
,, 37"—43"	3	8	14	20	
,, 43"—49"	4	10½	18½	26	36
,, 49"—55"	5½	14½	24	33½	44
,, 55"—61"	7½	19	30½	41	52½
,, 61"—67"	10	23½	37	49½	62
,, 67"—73"	13	28½	44	58	72
,, 73"—79"	...	34	51½	67½	83
,, 79"—85"	.	40	59½	77	94½
,, 85"—91"		.	67	86	105½
,, 91"—97"	...	...	75½	96½	118½
,, 97"—103"	...	.	83	105½	129½

TABLE II.—*Teak.*

Volume of timber in the round [illegible] definition)—quarter girth measurement—by girth classes and locality qualities to the nearest ½ cubic foot.

Girth class.	LOCALITY QUALITY.			
	IV	III	II	I
Over 7"—10" .	...		...	...
„ 10"—13" .	½	½	½	½
„ 13"—16" .	1	1	1	1
„ 16"—19" .	1½	1½	1½	1½
„ 19"—22" .	2	2	2½	2½
„ 22"—25" .	2	2½	3½	4
„ 25"—31" .	3	4	5	6½
„ 31"—37" .	5	7	9	11
„ 37"—43" .	7½	11½	13½	16
„ 43"—49" .	10	16	19	22½
„ 49"—55" .	14	22	26	30½
„ 55"—61" .	18½	28½	34	40
„ 61"—67" .	24	36	43½	51
„ 67"—73" .	29	44	53	63
„ 73"—79" .	35	53	64	76½
„ 79"—85"	..	62	75	89½
„ 85" 91" .		70	85	101
„ 91"—97" .	.	77	93½	113
„ 97"—103" .	..	8[illegible]	98	119½

TABLE III.—*Sal.*

Volume of timber in the round including bark (local C. P. definition)—quarter girth measurement—by girth classes and height classes to the nearest ½ cubic foot.

Girth class.	Height class.				
	11'–30'	31'–50'	51'–70'	71'–90'	91'–110'
Over 7"—10"	½	½	..	...	...
„ 10"—13"	½	1	.	...	...
„ 13"—16"	½	1	...	...	...
„ 16"—19"	1	1½	3	..	...
„ 19"—22"	1½	2½	4	...	...
„ 22"—25"	1½	3	5	...	...
„ 25"—31"	2	3½	6½	10½	...
„ 31"—37"	2½	5	9½	14½	20½
„ 37"—43"	..	6½	13	19½	27
„ 43"—49"		8	16	25	34
„ 49"—55"	..	10	20	31	41½
„ 55"—61"	...	13½	25½	37½	50
„ 61"—67"	...	17½	31½	45	58½
„ 67"—73"		22	37½	52½	67½
„ 73"—79"	..	27½	45	61	77½
„ 79"—85"	..	34	52½	70½	88½
„ 85"—91"	..	..	60½	79½	99½
„ 91"—97"	...	...	69½	89½	111½
„ 97"—103"	...	...	79	100	124

TABLE IV.—*Sal.*

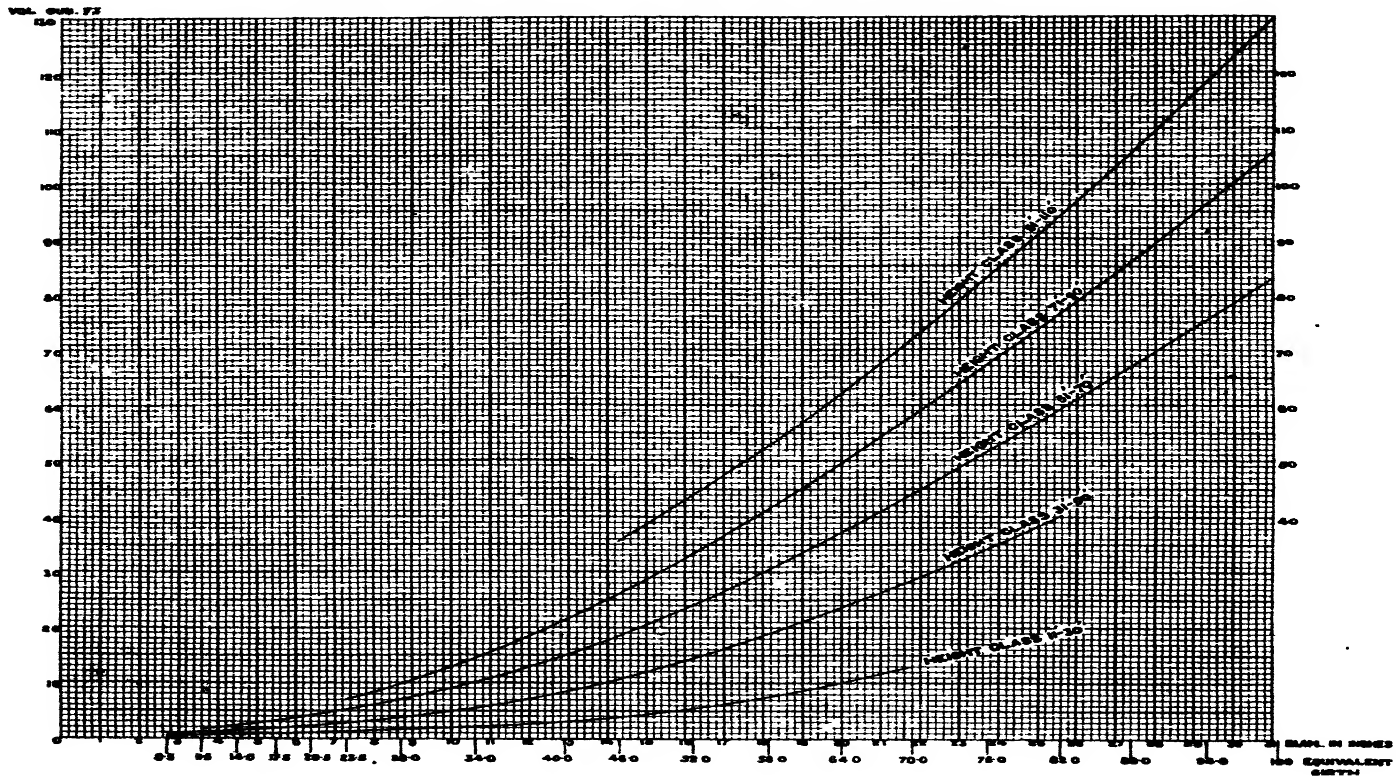
Volume of timber in the round including bark (local C. P. definition)—quarter girth measurement—by girth classes and locality quality classes to the nearest ½ cubic foot.

Girth class.	Local quality. III.	II.	I.
Over 7"—10" . .	...	...	...
" 10"—13" .	...	...	...
" 13"—16"	1	1	1
" 16"—19" . .	1½	1½	2½
" 19"—22" .	2½	3	4
" 22"—25"	3	4½	6
" 25"—31" . .	4½	6	9½
" 31"—37"	7½	11	15
" 37"—43"	11	16	21½
" 43"—49" .	15	21½	28½
" 49"—55" . .	20½	28	36½
" 55"—61" . .	26	35	45½
" 61"—67" . .	32½	42½	54½
" 67"—73" . .	39	50	64½
" 73"—79" .	46	59	75
" 79"—85" . .	54	68½	86½
" 85"—91" . .	61½	77½	97½
" 91"—97" . .	70	87½	109½
" 97"—103" . .	78½	98	122

CURVE NO. I

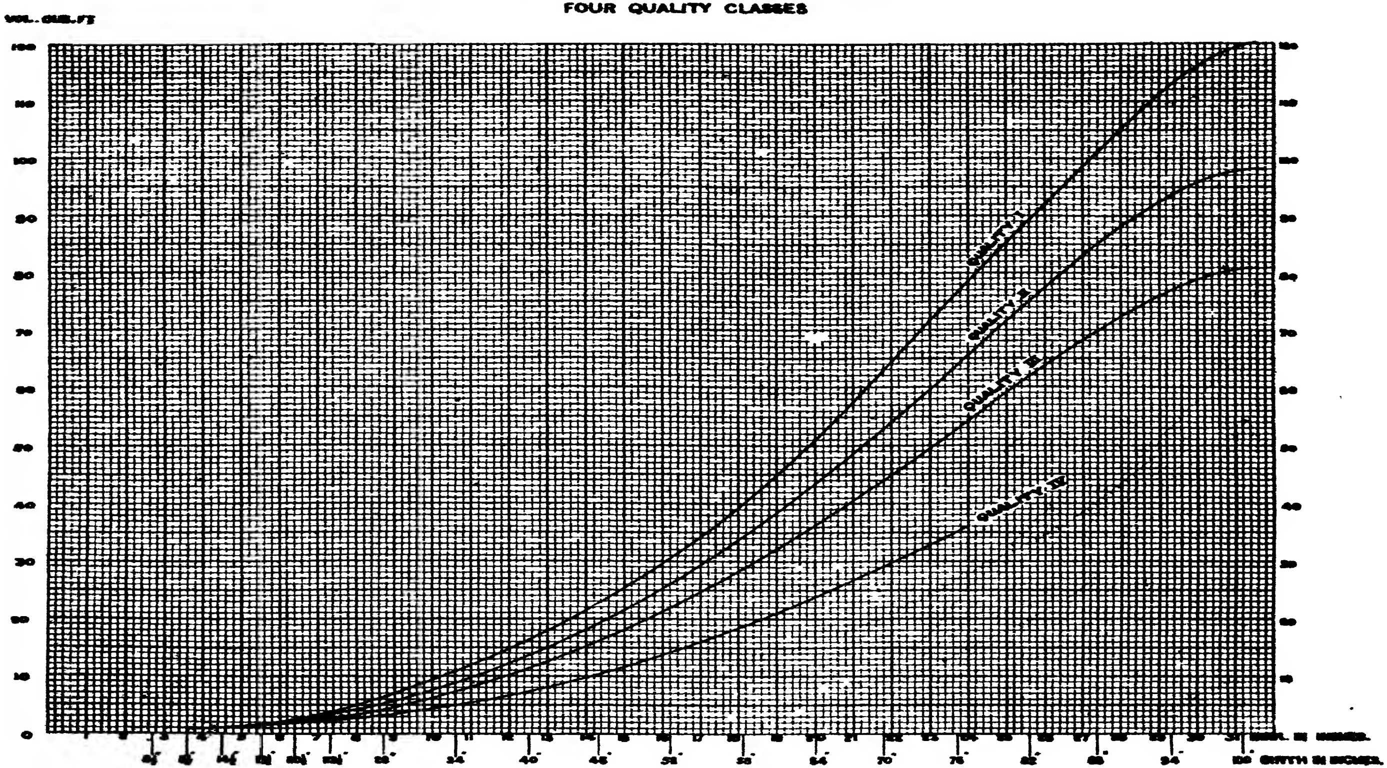
TEAK

VOLUME OF TIMBER IN THE ROUND INCLUDING BARK (LOCAL C. P. DEFINITION) QUARTER GIRTH MEASUREMENT
SHOWING VOLUME FOR 5 HEIGHT CLASSES & VARIOUS DIAMETERS.



TEAK

VOLUME OF TIMBER IN THE ROUND INCLUDING BARK (LOCAL C. P. DEFINITION) QUARTER GIRTH MEASUREMENT SHOWING VOLUME FOR FOUR QUALITY CLASSES

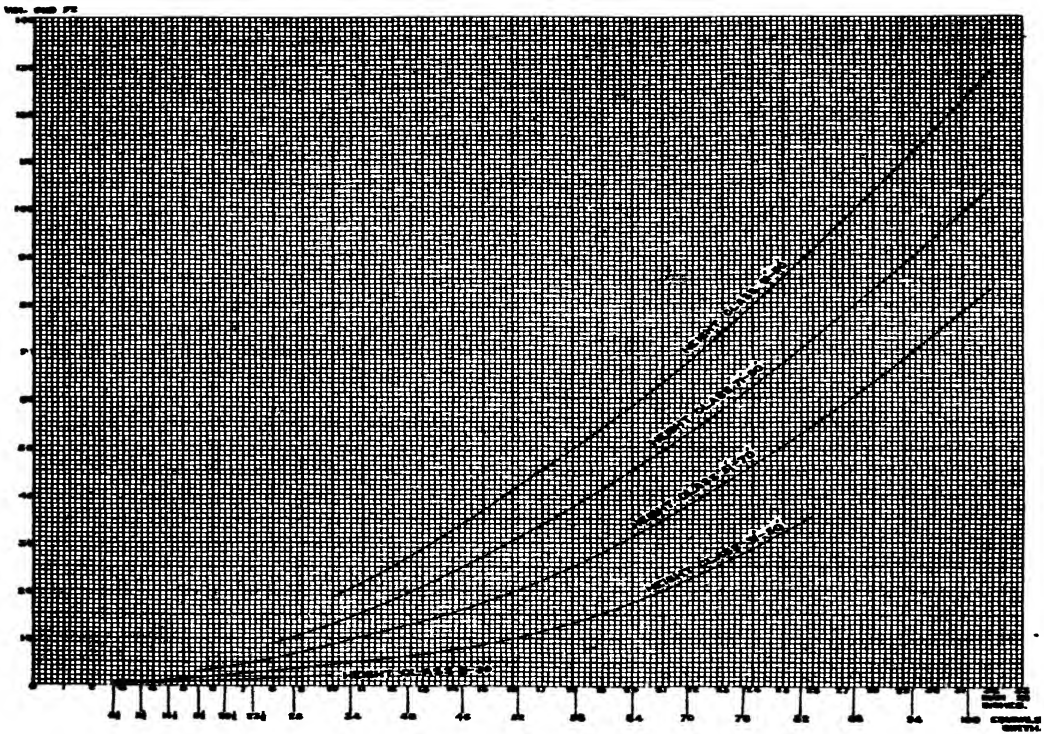


CURVE NO. 3

SAL

VOLUME OF TIMBER IN THE ROUND INCLUDING BARK (LOCAL C. P. DEFINITION) QUARTER GIRTH MEASUREMENT

SHOWING VOLUME FOR 5 HEIGHT CLASSES & VARIOUS DIAMETERS.

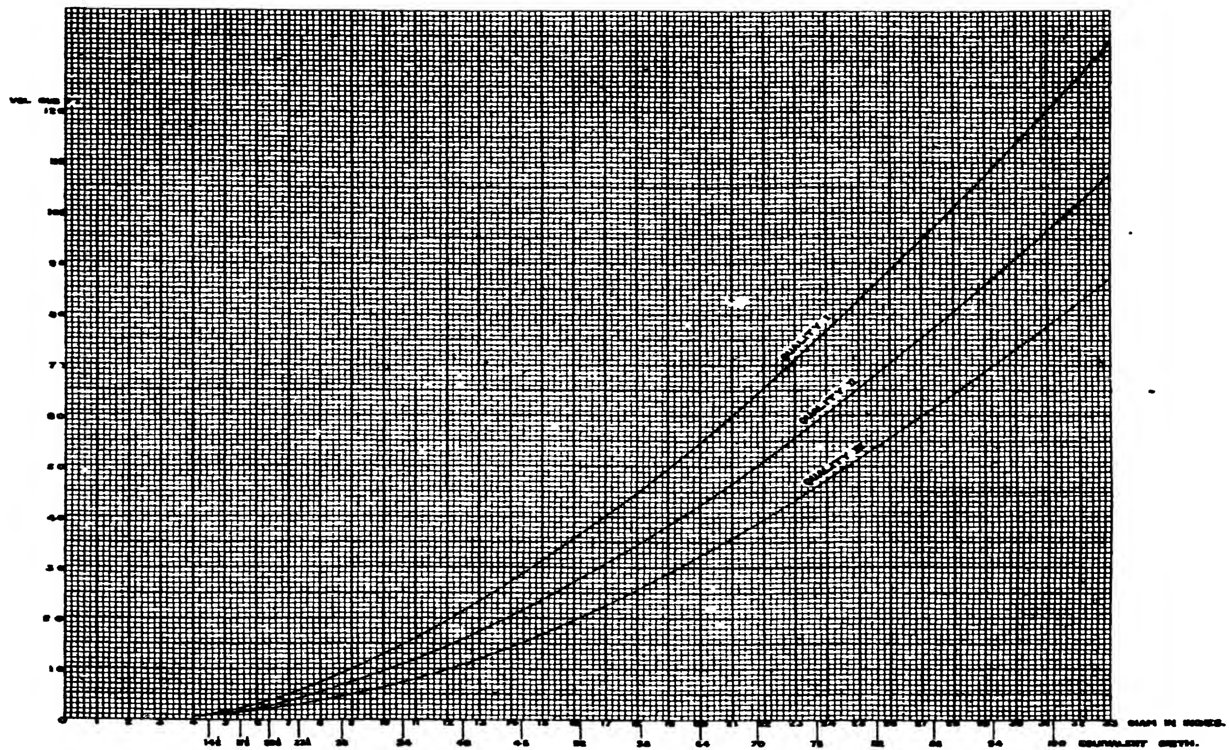


CURVE NO. 4

SAL QUALITY CLASSES

VOLUME OF TIMBER IN THE ROUND INCLUDING BARK (LOCAL C. P. DEFINITION) QUARTER GIRTH MEASUREMENT

SHOWING VOLUME FOR THREE QUALITY CLASSES.



INTRODUCTION.

This Record is the first of a series dealing with *Hoplocerambyx spinicornis* Newm., the large heart-wood borer of *sal*, a beetle of the family Cerambycidæ, and the most serious pest of *Shorea robusta*, itself one of the most important timber trees of India. A history is given of the course of an epidemic outbreak of this borer in Dehra Dun forest division; owing to the accessibility of the locality it has been possible for the Entomological Branch of the Forest Research Institute to make a continuous investigation since 1916. During the latter part of the period control operations have been enforced over the whole of the affected area of eight square miles with successful results.

It is customary and logical in entomological research to study fully the life-history and ecology of a pest, to base measures for its control on these data and to leave their utilisation to the executive forest officer. For practical reasons we have departed from this custom and are publishing first an account of a fair trial of the control measures devised for this pest together with that important corollary—an estimate of the financial and silvicultural success of the operations What the forest officer requires, it has been said, are not life-histories but death-histories, not suggested remedies but tested remedies

Concurrently with this investigation the borer-fauna of *sal* has been studied as a whole. More than a hundred species enter into the formation of this complex, some of which attain primary importance in regions where *Hoplocerambyx spinicornis* is scarce Subsequent publications will deal with the life-history and ecology, and the morphology of the adult and early stages of *Hoplocerambyx* and of the more important species of *sal* borers

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Forest Entomologist.

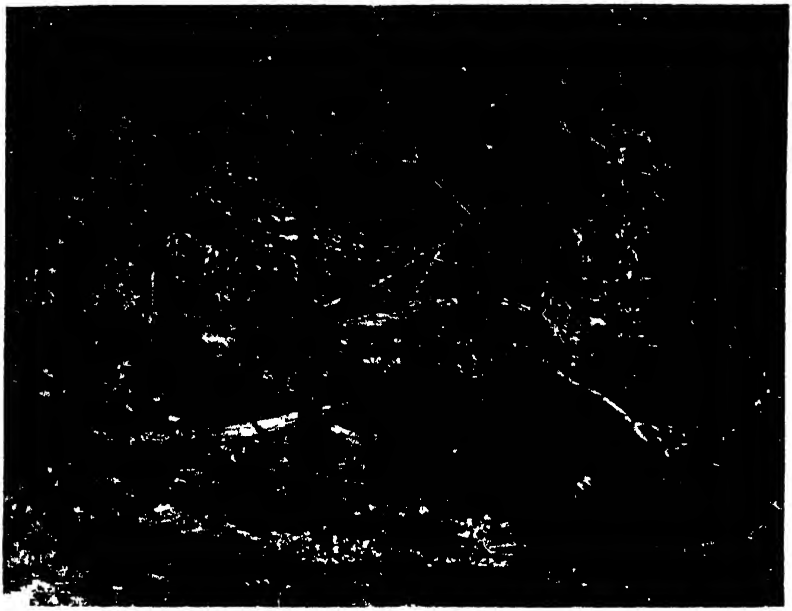

Fig. 1. Felling refuse left in the forest after removal of the timber. The heartwood borers breed in this material and attack fresh trees in the following year.

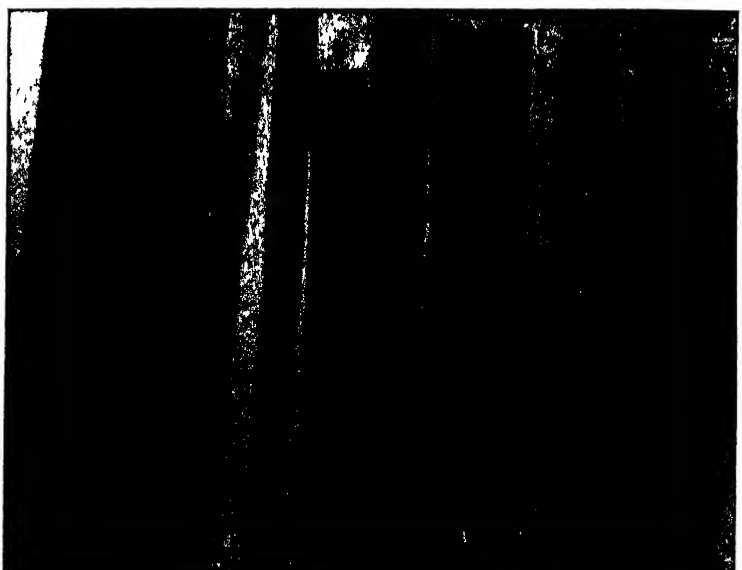

Fig. 2. *Sal* beams and poles riddled by the large heartwood borer (*Hoplocerambyx spinicornis*). These have been cut from logs seasoned with the bark on, and from killed standing trees.

INDIAN FOREST RECORDS

Vol. XI.] 1924 [Part VIII

The Economic Importance and Control of the *Sal* Heartwood Borer (*Hoplocerambyx spinicornis* Newm., fam. *Cerambycidae*)

BY

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A DESCRIPTION OF THE AREA.

The Thano *sal* forests form a compact block of 5,086 acres, or nearly eight square miles, in the north-east of the Dehra Dun Division between the Malkot Hill and the Song River. The area has been under concentrated regeneration since 1903, and in 1911 the prescriptions were completely revised, primarily, to provide an object lesson for the Forest College in the practical appiication of concentrated regeneration fellings. At the revision of the working plan of the Dehra Dun Division in 1924 the area was again treated as a separate Working Circle.

As the distribution of the attack of *Hoplocerambyx spinicornis* during the epidemic described in this Record appears to have been largely influenced by the configuration of the ground, it is necessary to give a detailed topographical description of the area.

The forest stands on a broad river-terrace or plateau (*chaor*) formed apparently of detritus. The only geological map available (Medlicott, Mem. Geol. Survey, III, 1864) shows the tract as occupied by the upper beds of the Himalayan series (Krol, *infra*-Krol and Blini); the Siwalik formation is shown at the level of the Song bed.

The *chaor* starts abruptly at the foot of Maidan Hill at a level of c. 2,500 ft., and slopes gently south-west for about 3½ miles to the bed of the River Song, where it terminates near the 1,850 feet contour-line in a scrap 25-150 feet high, steepest in the north. Laterally, the area is bounded by two stream beds; on the north-west by the deep narrow ravine of the Rihar Rau, and on the east and south-east by the broader bed of the Bidhalna Rau.

The drainage of this terrace is carried out by typical consequent streams. In the early stages of its development three main consequent streams became established, but their later history has not been similar, and these differences affect the modern position of the subsoil water-level The Lambi Rau and the Palasi Rau have developed tributary gullies mainly on their northern banks, and have extended their heads into the main hill-region above the 2,500 feet contour The catchment-area of the Lambi Rau in the hill-region and in the terrace is smaller than that of the Palasi Rau; its western branch the Siron Rau, is a long, deep ravine without tributaries, and its main eastern branch, the Ghandol Rau, is in its upper reach an obvious pirate gully, that has captured some of the head-waters of the Palasi Rau The Palasi Rau has three main branches, of which one, the Beloghat Rau, has a considerable catchment-area in the hills, while the others and the lesser tributary gullies collect their water mainly in the upper levels of the terrace.

The gullies in the south-east portion of the Reserve are of a different type; they are drainage lines, that have been betrunked by the lateral erosion of the Jakhan River, which formerly joined the main Song River higher up-stream. The lower courses of these gullies are replaced by a river-terrace at a lower level (50 feet) across which they do not extend. That they are of the same age as the Lambi and Palasi Raus is evident from the present appearance of the de-energised Bago Khala, which is no longer corroding its bed In consequence of the alteration in their base-level and gradient, these gullies have not extended headwards so rapidly, and the area traversed by them is much less dissected, than that of the two Raus above mentioned.

The floors of these gullies, even in the case of the larger Raus, are nowhere more than 50 feet below the level of the plateau; the average depth is 20 feet. Except when rain is falling they are dry.

Throughout the tract the permanent subsoil water-level is very low and attempts to dig wells have failed. Springs occur at the junction of the terrace with the hill-side at about 2,500 feet, due apparently to change in the inclination or nature of the strata, and water again reappears at ground level at the foot of the terrace at 1,750 feet. A large *tappar* occupies compartment 33 and grassy blanks occur in compartments to the south of the 1,950 feet contour.

THE HISTORY OF THE EPIDEMIC.

1916: While carrying out the usual annual selection markings under the Working Plan prescriptions of 1915-16, in December 1916, the marking officer, Pandit Tula Ram, Extra Assistant Conservator of Forests, discovered serious damage by insects in compartment 25. Trees of 3′-6′ in girth were found dead or dying with heaps of wood-dust at their bases, necessitating the marking of hundreds of trees, that would ordinarily not be removed under the directions of paragraph 62 of the Working Plan for the Thano Forest, 1911. The same state of affairs was suspected to occur in the adjoining compartments 26 and 27, which are said to have shown no signs of damage, when enumerated by the same officer in the previous spring.

1917: In January 1917 the Divisional Officer, the President and other officers of the Forest Research Institute inspected several compartments and it was generally agreed that the dying-off of trees was due to the attack of the large heart-wood borer of *sal*, *Hoplocerambyx spinicornis* Newm., and was sufficiently extensive to warrant the immediate adoption of remedial measures. The advisability of departing from the working-plan prescription of that season was also considered.

The life-history of *Hoplocerambyx spinicornis* in the United Provinces had at this date not been studied seriously, and such as was known of its bionomics was based on misconceptions due to Stebbing's confusion of the species with *Aeolesthes holosericea* Marking-rules to meet the emergency were devised by the Forest Zoologist, and an enumeration of the whole forest was undertaken by parties under the direction of Mr. Daya Ram, Extra Assistant Conservator of Forests and the junior author with the assistance of students of the Provincial Service Class under Mr. J. G. Douglas-Hamilton, Instructor. A total of 6,772 attacked *sal* trees was recorded. This number represented the trees that had been attacked by the borer in the rains of 1916, together with any trees killed in the previous years in unworked compartments.

Various opinions were held as to the cause of the borer outbreak. There was a general tendency to consider that the majority of trees in the crop consisted of over-mature and unhealthy individuals which on this account readily succumbed to the attack of the insect. (*Vide* Annual Progress Report of Forest Administration in the United Provinces for 1916-17, page 11). It was suggested, moreover, that the dying-off of *sal* in Thano was not unusual, but was paralleled by similar occurrences in the past in other forests of the United Provinces. On the other hand the remedial measures proposed by Mr. B. B. Osmaston, President, Forest Research Institute (acting Forest Zoologist) emphasised the necessity of felling and removing the attacked trees before the rains of 1917 if the damage were to be checked whatever the cause and extent of the outbreak.

In March, the Chief Conservator, United Provinces, decided that these measures involved operations on too large a scale to be carried through before the close of the working-season, and that extraction should be postponed. The trees were auctioned in the autumn of 1917, and felled in the period November, 1917—March, 1918 and were left lying in the forest until the following year. The effect of this decision on the progress of the borer attack may be deduced from the following fact in the insect's life-history. The borers that were breeding in the marked trees, completed their development and emerged as beetles in July and August, 1917. These broods then proceeded to attack other trees in the neighbourhood of the original centres of infestation, so that the 1917-18 generation of the insect was established before the infested trees of the previous year were felled.

The senior author on return from Mesopotamia reported on the position in December 1917, pointing out that the delayed conversion of the 1916-17 trees had resulted in an extension of the attack on a much more severe scale. The total number of *sal*, marked as newly-infested in 1917, reached 10,432. The incidence of attack on the I-IV girth classes varied between 10 and 50 per cent. in most compartments, and in places had risen to 100 per cent., as against 8 to 20 per cent. in the previous year The extraction of the newly-attacked trees before April, 1918, was evidently a matter of urgent necessity, if the growing stock in Periodic Blocks II and III was to be protected. As a remedy it was advised that (*a*) the contractors working on the previous years' trees in the heavily-attacked compartments should be persuaded by favourable terms to extract or convert the trees of the present year's attack, or (*b*) felling and conversion should be undertaken departmentally, or (*c*) if conversion was impossible, extraction in the round to the depots outside the forest should be attempted departmentally from the most severely attacked areas.

Measures were also proposed for the utilisation of attacked trees in unworked parts of the forest for the trapping of broods of the borer in the early rains of 1918. The marking-rules were designed with the object of removing at one felling the maximum quantity of infested trees in the most seriously affected parts of the forest.

1918: The remedial measures advised by the Forest Research Institute were considered by the Chief Conservator as impracticable even if not impossible, and further he doubted whether they would be effective if carried out. As an alternative solution he proposed (January 1918) that "all infected trees should be at once felled and left unconverted and unbarked in the forest. These will form a complete trap and *all* emerging insects will lay their eggs in them since they prefer felled timber. The trees can then be converted next year (1919), and the refuse burnt if necessary before March."

As these measures were eventually put into force in place of those recommended by the authors, it is desirable to explain why they were not supported by expert opinion. The infested trees representing one year's attack fall into two groups, (*a*) heavily-attacked trees (*i.e.*, trees of which the whole bark is destroyed by the boring larvae), and (*b*) slightly-attacked trees, (*i.e.*, trees of which only a portion of the bark is destroyed). The assumption made in the Chief Conservator's remedy is that the trees slightly-attacked in 1917-18 would be sufficient to provide breeding-material in 1918-19 for all beetles emerging from them, as well as for the beetles emerging from the fatally-attacked trees. The ratio of slightly-attacked trees with large areas of undestroyed bark, to fatally-attacked trees, affording no breeding facilities, is one important factor; and the rate of increase in numbers of the beetle from year to year is another important factor. Only if these two are of equal value will the felling of attacked trees to serve as traps prove an effective remedy. The rough enumerations made by the authors showed that the value for the former ratio was approximately 1, and the value for the rate of increase of the beetle was about 5. Hence it was estimated that the 1918 beetles would require at least 14,000 trees to breed in, whereas only 5,000 trap trees would be available,* and the United Provinces Forest Department was advised that the proposed remedial measures would not obtain the result desired.

The scheme was nevertheless adhered to, and the 11,440 trees of the 1917 attack were felled in May-June, 1918, and left in the forests throughout the rains with the previous year's yield.

1919: During the period November, 1918—April, 1919 the trees attacked in 1916 and 1917, that had already been felled were removed

* A year later it was found that 27,480 fresh trees were attacked in addition to the 11,440 trees felled.

from the forest. In March, May and June, 1919 the attack of the rains of 1918 was enumerated by the Divisional staff and a total of 24,518 living *sal* was discovered to be infested. In pursuance of the same policy these trees were felled and in the autumn were sold.

As an experiment, the Forest Zoologist was permitted to apply his remedy to a small area involving four compartments, from which the infested trees were removed in April-May, 1919 (*vide* page 30).

It was now becoming obvious to the Forest Department of the United Provinces, that the borer attack in Thano forest was not being checked as anticipated. The felled 1917 trees had failed to act as traps, and the number of the felled 1918 trees had now risen so high that their removal constituted a task beyond the capacity of the contractors. A new dilemma was introduced by the practical difficulties of felling unsold trees in the same coupes as sold trees. The high death-rate was also beginning to make itself felt on the provisions of the working-plan, and in October 1919, Mr. S. H. Howard, Silviculturist, observed that if the annual attack killed more trees in Periodic Blocks II to VI, than would ordinarily be removed sylviculturally, or even killed trees other than those that should be removed sylviculturally, the proposed conversion of the forest from selection to uniform could not be continued. The whole possibility was already being removed from Periodic Block I, and if more than the total possibility of the forest were removed annually, it was only a question of time before the forest ceased to exist.

When the necessity arose for deciding on the operations of the season 1919-20, Mr. F. F. R. Channer, Conservator, Western Circle, proposed to discontinue the marking and felling of insect-attacked trees for 1919 with a view to adopting the measures recommended by the Research Institute in the next season, 1920-21. The matter was therefore referred to the Forest Zoologist for advice.

In November 1919, a scheme was designed with the objects of (*a*) obtaining an annual yield of attacked trees in numbers small enough to be handled by the available local labour-supply, (*b*) conducting the operations on a revenue basis, and (*c*) checking the insect-epidemic in two or three years. The proposals may be summarised as follows:—

1. Abandonment of the enumeration of attacked trees in the season 1919-20.

2. Enumeration of the whole forest as late as possible after the rains of 1920, marking for removal (*a*) leafless trees, (*b*) trees with withered foliage, (*c*) trees with green foliage and very large heaps of wood-dust at the base; thereby

neglecting (*d*) green trees with small or inconspicuous amounts of ejected wood-dust, and (*e*) green trees with dammar flow.

3. Felling and removal of marked trees, with felling refuse down to one-foot-girth, before March 31st, 1921, with extension to April 30th, 1921, if required.

The trees were to be sold standing on favourable terms to ensure the removal of all felling refuse, lop and top, unconverted timber, etc., down to one-foot-girth. If the yield from this source were less than the annual possibility under the normal prescriptions, additional fellings should be made of trees classified under (*d*) and (*e*) of section 2 above, in compartments due for working.

1920: The measures were eventually adopted with slight modifications in June, 1920, and put into force at the end of the year. The 27,480 trees of the 1918 attack contained a very high proportion of slightly-attacked trees which were felled green in 1919 in a condition suitable for reinfestation. In 1918-19 only 10 per cent. of the trees marked were dry or leafless, whereas in 1917-18 over 40 per cent. were dry trees. It was expected, therefore, that the 90 per cent slightly-attacked 1918 trees would absorb a large proportion of the 1919 attack, but this effect could not be measured as the felled trees were extracted in the period November, 1919 to June, 1920, and no enumeration of the 1919 attack was undertaken.

It was also expected that the revised marking-rules would result in the selection of the most heavily attacked trees, but that a proportion of the infestation in the form of slight attacks would be left over until the following year. During September, 1920, Thano forest was surveyed by the divisional staff for insect-attacked trees, and a total of 3,605 *sal* was recorded. This figure represents the trees that had died as a result of the 1919 attack, *plus* a small proportion of the 1920 attack. The period in which the enumeration was made was much earlier than desirable, for the 1920 attack had not developed sufficiently by the beginning of October to permit the detection of any but the heavily-attacked trees. The Divisional Officer was advised to arrange for the contractors to remove such trees as died off in their coupes during the subsequent working-season. Probably an additional couple of thousand trees showed evidence of infestation before the spring of 1921, but the number taken over by contractors, of which records are available, was only 250. The total removal of insect-attacked *sal* in 1920-21 was, therefore, 3,855. These were sold at an average price of four annas per tree.

1921: The control measures based on principles advocated by the Forest Zoologist in 1917 had at last been adopted, and had been put into force in the season 1920-21. Their effect should, therefore,

have been visible in the season 1921-22, if correctly applied and if conditions remained unchanged. But owing to the early date of the enumerations of 1920 it was evident that the control measures had not operated with full force and would show only partial effect in the following season. It had also been discovered from experiments conducted in the forest and the insectary, that the divergence of the annual rainfall from the mean was a factor that affected the success of control operations; and that this factor should be taken into account over a series of years in estimating the value of the remedial measure.

A third factor was introduced by the Divisional Officer, who conducted a subsidiary experiment involving five compartments having a total area of 291 acres. This officer burned all the felling-refuse, climbers and undergrowth on the area in compartments 54-58 on the 18th April, with the object of destroying all breeding-material not removed by the contractors. He found it was not possible to burn over the area without danger to the standing crop, as "some of the healthy green trees were badly scorched by the intense fire caused by the dry stuff at their bases". He proposed to continue the burning in the month of February in subsequent years, and to extend the area until the whole forest had been burned over,—an operation that would take fourteen years. On the advice of the senior author he was dissuaded from continuing the experiment.

The 1921 attack was enumerated over the whole of Thano forest between the 15th October—16th November 1921, and a total of 5,825 *sal* attacked by *Hoplocerambyx spinicornis* was recorded. Of this number 1,628 trees or 28 per cent., were located in the five compartments burned by the divisional officer. That the whole of 1921 attack had not been recognised by divisional enumerators, was discovered from sample surveys made by the junior author in December, which indicated a deficit of about 37 per cent. The trees were felled in December 1921—February 1922, and extracted before the end of April 1922 They were sold at an average price of twelve annas per tree.

1922: Although it is desirable to postpone the enumeration of the attack of the *sal* borer as late as possible into the cold weather in order to recognise all the trees that should be removed, it was not possible to do so in 1922. The enumeration was made between the 1st and 21st November by Deputy Rangers and Foresters with a yield of 4,411 trees These were felled during December 1922—February 1923 and extracted before the 1st of May 1923

1923: The enumeration of attacked trees by divisional agency was completed in December. A portion of the work was checked by the Forest Entomologist, as a result of which the Divisional Officer

re-enumerated the forest and obtained a total of 2,625 trees. This is equivalent to an attack on one per cent. of the growing stock. By four-inch girth classes the actual percentages are:—

8"—12".	12"—16".	16"—20".	20"—24".	24" and over.
1·12	0·86	0·81	1·31	0·80

1924: The total attack was 1,438 trees.

THE ORIGIN OF THE EPIDEMIC.

From the present evidence on the geographical distribution of the large heart-wood borer of *sal* it may be accepted that the insect is naturally established, *i.e.*, endemic, in the moister forests of the *sal* habitat, and in the northernmost extensions in the Gangetic plains. Dying or felled trees form the insect's normal breeding-material in which it maintains a numerical abundance, that does not permit the infestation of more than one standing *sal* tree per acre per annum. Its normal endemic incidence is probably much lower. Under epidemic conditions, such as occurred in Thano, and possibly in Bhira, South Kheri, Lachmanmandi in Haldwani, or Chakia and Motipur in Bahraich Divisions, the attack on standing trees may reach 100 per cent. locally.

The causes which led up to the Thano epidemic, detected in 1916 are obscure, but an examination permits many of the likely factors to be discarded.

1 FELLINGS.—The conduct of the fellings under the 1910 working-plan is a possible contributory factor, on the supposition that the lop and top and unconverted portions of logs serve as breeding-material. Compartments in which fellings have occurred should show a higher degree of attack than those untouched by fellings. On this assumption compartments 30 to 34 should show signs of attack in the cold weather of 1916-17 with increased intensity in 1917-18. Compartments 23 to 26 should show initial attack in 1917-18. Actual conditions do not agree with this hypothesis:—

		In 1916.
Compartments	3, 4, 5, 6, 7, 16, 17, 18, 19, 20, 21, 22, 23	show *very weak* attack.
	24, 25, 26 . .	show *strong* attack.
	31, 32, 33, 34 . .	show *very weak* attack.

On the other hand compartments in which no fellings have occurred, *e.g.*, Periodic Blocks II—III and the northern part of the forest, show the heaviest attacks. A comparison of the proportion of dry trees in the outturn of coupes in Thano previous to 1916 is of interest.

Proportion of dry sal *trees in regular coupes.*

Latest year of attack.	Year of sale.	Compartment number.	Percentage of dry *sal* trees.
1911	1912-13	14 and 15	6·7
		16, 17, 18	3·1
1912	1913-14	19, 20, 29	6·3
		21, 22	11·3
1913	1914-15	31	5·8
		33	1·7
		34	4·8
1914	1915-16	23	8·2
		24	31·7
		25 (part)	34·3
		26 (part)	25·0
		1	3·1
1915	1916-17	25 (part)	22·3
		26 (part)	24·5
		27, 28	13·2
		41, 42	5·5
		1 (part)	6·0
		2	2·6

From the table above it is evident that the epidemic was already in existence in compartments 24, 25 and 26 as early as 1914. Corroboration of the early development of the outbreak is available from records made by the Forest Zoologist of groups of freshly attacked trees in compartment 47 in October 1913, and in compartment 31 in the spring of 1914.

The fellings are therefore not to be regarded as a contributory cause of the epidemic.

2. FROST DAMAGE.—The compartments most seriously attacked by the borer were those that suffered least from the frost of 1905.

3. THE HEALTH OF THE GROWING STOCK.—The general opinion as to the health of the growing-stock is expressed in the Annual Report of the Forest Administration in the United Provinces for 1916-17, page 11:—"the affected trees were all overmature and hide-bound and, in short, were in an unhealthy condition and should not have been left in the crop so long".

In the following year other causes were instanced as responsible for the epidemic, *vide* the same publication for 1917-18, page 10. "They (the trees) are almost all commercially mature and their removal will benefit the forest. There must have been something

wrong with the crop for an attack to make such headway, as the insect concerned is always in existence sporadically in our forests. A great many over-mature trees had without doubt been retained in the crop owing to faulty prescriptions in the working-plan aiming at too large an exploitable size for the locality. There were other causes too. It has been observed that anything that tends to check the flow of sap favours the growth of the young *Hoplocerambyx* larvae In this case the trees suffered badly in 1916 from attacks by defoliating caterpillars. This checked the flow of sap. Then in 1917, owing to the continuous rain and cloud there was little direct sunlight during the growing season. Transpiration was reduced and consequently the flow of sap checked. It is believed that these causes enabled the usual sporadic attacks to become general".

In the following year the Annual Report for 1918-19 says: "These (insect-attacked) trees were of all sizes and qualities and the attack is by no means mostly confined to mature and unhealthy trees. The Forest Silviculturist found that the type of *sal* tree in Thano which had been considered from the appearance of its bark to be stagnating and unhealthy is actually putting on an excellent annual increment".

In 1919-20 the normality of the health of Thano *sal* is accepted, but "it is considered that Thano forest was so overstocked that the attack, severe as it has been, has not resulted in a serious over-felling" (A. R. F. A., U. P , 1919-20, page 9, paragraph 37).

By 1923, however, conditions had changed this view and we find the Working-Plan Officer treating Thano forest as a separate Working-circle apart from the rest of the *sal* forests of the Division, because "the severe attacks of *Hoplocerambyx* necessitate the calculation of the yield on the whole volume of the growing-stock and the removal of all the attacked trees before any other fellings are made". (Working Plan, Dehra Dun, 1923, page 65, paragraph 112).

4. THE ANNUAL RAINFALL.—In 1921 the senior author suggested that "the annual rainfall is an important factor in the dying-off of *sal* and in the efficiency of the borer attack in a *Hoplocerambyx* endemic area". (Beeson, 1921, Indian Forester, pages 69-76). It was considered that rainfall above the normal for the foot-hills of the outer Himalayas is favourable to the development and reproduction of *Hoplocerambyx spinicornis* and that, *per contra*, rainfall below the normal causes reduction in the abundance of the insect. "The emergence period of the beetle is directly influenced by the initial date of the rains and their extent, through their effect on the moisture-content of the heart-wood of *sal* and the relative atmospheric humidity of the pupal chamber of the borer lying in the heart-wood. In a wet year some 75 per cent. of the beetles emerges in the first

month of the rains; in a dry year the period is prolonged to six or eight weeks. Assembling, pairing, and oviposition are facilitated and the possibilities of mass-attacks are increased; there are, moreover, indications that in seasons of deficient rainfall fecundity and longevity are decreased" (*loc. cit.* page 70). Studies in the effect of rainfall on the ecology of *Hoplocerambyx* have been continued, but it is beyond the scope of this Record to discuss the additional evidence for the validity of the hypothesis outlined above.

The article quoted suggested further that abnormalities in the annual rainfall affected the resistance of the host-tree, *sal*, to the attack of the borer, in so far that a series of wet years might produce unfavourable conditions of soil-aeration, that react on the vitality of the tree. (See Plate V, fig. 1, for annual rainfall.)

THE ANNUAL INCIDENCE OF THE BORER AND THE ANNUAL DISTRIBUTION OF THE ATTACK.

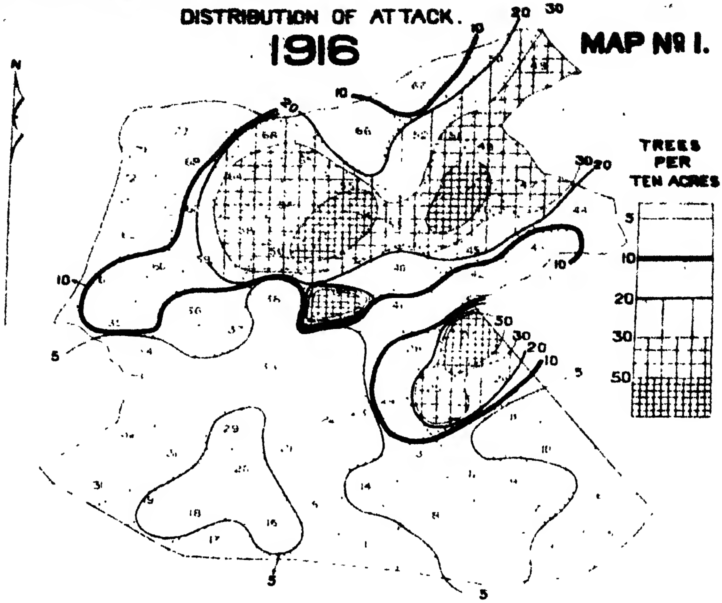
The following table gives the total number of trees marked as insect-attacked for each year of enumeration. These figures do not represent the actual abundance of the insect and are not directly comparable *inter se*.

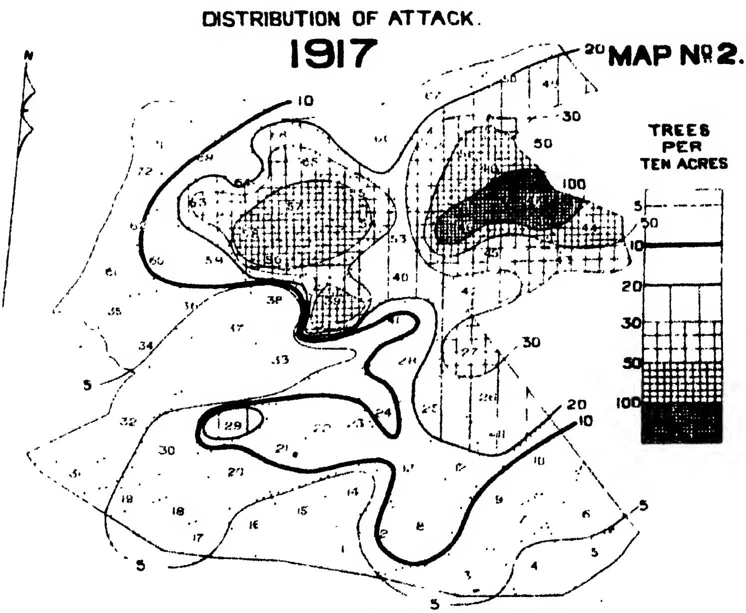
Annual enumeration of sal trees, Thano.

Year of attack.	No. of trees marked as attacked	Year of attack.	No. of trees marked as attacked.
1916	6,772	1920	3,855
1917	11,336	1921	5,825
1918	27,480	1922	4,411
1919	No enumeration.	1923	2,625
		1924	1,438

1.—THE AREAL DISTRIBUTION OF THE ATTACK.

Since the compartment has been generally used as a unit in carrying out the enumeration of attacked trees, it has been possible to prepare maps showing the severity of the attack from year to year. (*Vide* Plates I—IV, Maps 1-8 and Appendices I and II.) The degree of attack per compartment has been reduced to the common index of *number of attacked trees per acre*. In the distribution maps (to avoid the use of decimals) the contour lines represent the number of attacked trees per *ten* acres, *viz.*, 5, 10, 20, 30, 50, 100, 200 and over.





Distribution of attack of *Hoplocerambyx spinicornis* in Thano Working Circle

[*Scale—1 Inch to a Mile.*]

1916: In the first year of special enumeration the trees marked included those attacked in the rains of 1916, those that had died as the result of the attack of 1915, and possibly of several years previously (*Vide* Origin of the Epidemic, page 10) At the time no attempt was made to identify the trees attacked in 1915 and previously, but from other data it is estimated that at least 2,000 of the dry trees should be considered to have been killed in 1916, and a probable 1,800 date from 1915 and previously. These trees were located principally in compartments 25 and 27; 39, 46 and 47; 48; 51; and 52, *i.e.*, in areas which are among the most severely infested in subsequent years. The areal distribution of the attacked trees surveyed in 1916-17 is given in Map No. 1, plate I

1917: In 1917 the enumeration figures represented more closely the actual distribution of the epidemic in the season 1917-18. Two large centres of heavy infestation were revealed—a north-eastern focus composed of compartments 44, 46, 47, 48, 51, and a north-western focus comprising compartments 54-58 with an outlier in 39; these areas represented a direct extension of the attack from the previous year's foci There was a general slight rise in the incidence over the southern part of the forest; but the high degree reached in 1916 in compartment 25 and 27 was followed by a definite decrease, while towards the south-west the abundance of the borer did not materially alter. (*Vide* map No. 2). In this year an attempt was made to place the attacked trees in two classes, (*a*) dead trees with brown or fallen foliage, and (*b*) green trees, on which the attack had not been severe enough to cause death by the date of enumeration. A total of 3,987 or 89 per cent. was found to be dead by March, 1918 The areal distribution of the dry trees conforms very closely with that of the total attack, compartments 44, 46, 47, 48, 51 form a region of high mortality; compartments 54-57 form another, and compartment 39 is similarly isolated It may be noticed that the compartments with the heaviest infestation form a zone in the middle and lower reaches of the principal tributary gullies, all of which converge near the level of the 1,195 feet contour-line below which the gradient flattens out. The trend of the height contour-line is N. W.-S. E., more or less parallel to the eastern boundary line between Government and Zamindari forest.

1918: The attack of 1918 was the most serious recorded for whole period, exceeding 27,000 trees It has been suggested that the forest was much over-marked and that the attack was actually not so serious. The rate of increase in the number of trees marked is 2·4 as against 1·7 from 1916 to 1917; but if the accumulated trees prior to 1916 are subtracted from the enumeration total of 1916, the attack of 1916 comprises about 3,500 trees, so that the actual rate of increase from 1916 to 1917 is nearer 3·3 times. In the writers' opinion this rapid increase did occur, and was much facilitated by the felling of the attacked trees. Unfortunately the divisional

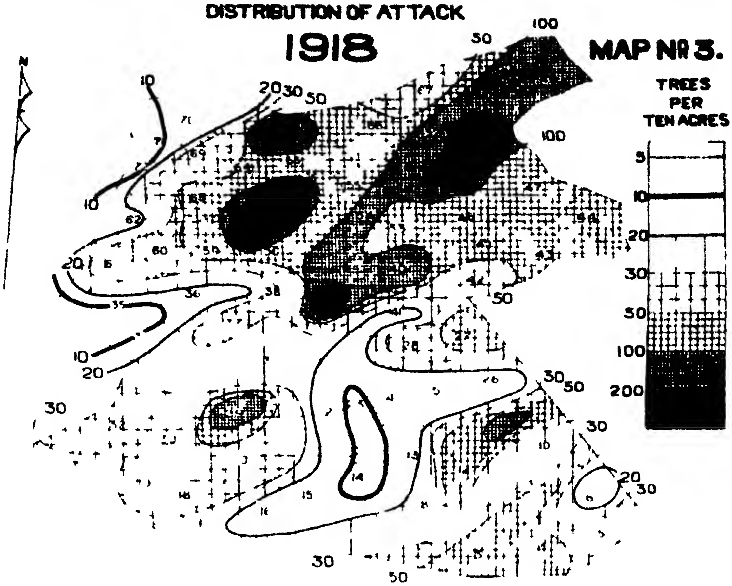
enumerators used a new system of defining and classifying the evidence of attack, lumping the bulk of the attacked trees under the term "Green", instead of using the sub-classes "Green", "Half-green," and "Leafless", that had been previously adopted. A check on the regularity of the markings is not possible on this basis.

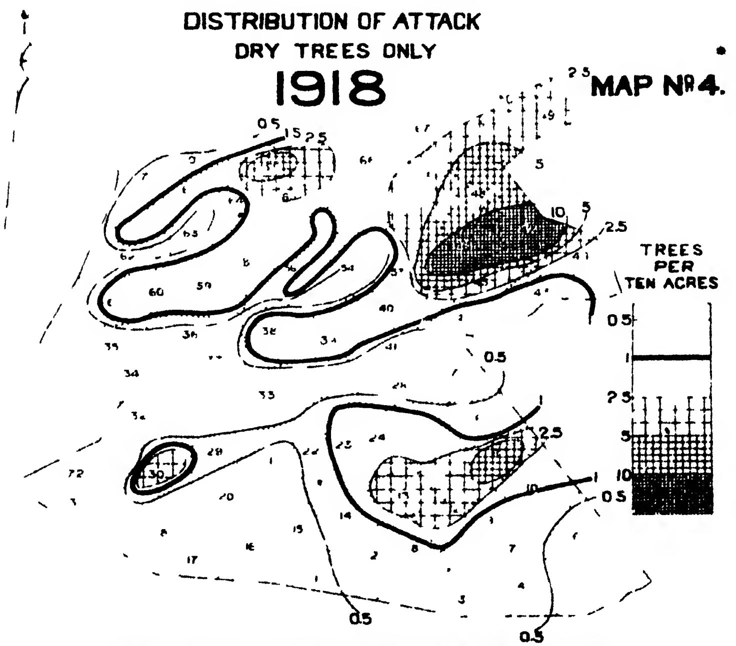
The chief features of the distribution in this year are the extension of the area of heaviest incidence over the whole of the northern part of the forest, and a proportional increase over the southern part; the appearance of new foci in compartments 29, 11, and 68; and the occurrence of a central zone of low attack around compartments 28 and 14 (*vide* map No. 3). The "dry" trees form a very low percentage of the total and their distribution (as shown in map No. 4) does not conform so closely with that of the total attack, which may indicate lack of uniformity in the markings, at least in time. The year 1918 was, however, a drought year with less than half the rainfall of the previous year (55·57 inches against 119·33 inches), and this may be responsible for the discrepancy. It is believed that the delayed and weak monsoon of 1918 acted as a serious check on the reproduction of the borer and reduced the severity of the attack on the individual tree. In consequence the proportion of *sal* trees killed outright was lowered, and also the proportion of beetles surviving successfully to the rains of 1919 was heavily reduced. Although emerging at its maximum abundance in 1918, the insect was able to carry out only a diffuse and weak attack; paradoxically, its year of maximum abundance was that of its least strength.

1919: The incidence of 1919 must remain unknown, as no enumeration was carried out, except in a few compartments used by the Forest Entomologist as sample plots.

1920: In 1920 the marking was done according to the new rules prescribed for control measures, which aimed at removing only the killed trees, and those so heavily attacked, that death was likely to ensure during the course of the life-cycle of the borer. Hence a yield was obtained, which, in comparison with those of the uncontrolled period 1916-1918, appears very low. The total also included those trees, that had died as a result of the attack of 1919 and consequently were still standing in the forest in the autumn of 1920. (*Vide* map No. 5). *It must again be emphasised that the enumeration figures of 1920-1923 are in no way comparable with those of 1916-1918 as an index of the severity of the attack.*

1921—1923: Exactly the same methods of marking were adopted in the three years following, so that the quantities obtained represent, in each year, part of the current year's attack and the balance of the previous year's attack, that became recognisable after the





Distribution of attack of *Hoplocerambyx spinicornis* in Thano Working Circle

[*Scale—1 Inch to a Mile*]

completion of the enumeration. The effect of the remedial measures in reducing the actual abundance of the insect (as opposed to the reduction of the yield of attacked trees) does not begin to operate until after the extraction of the 1920 trees, *i.e.*, the enumeration of 1921 is the first that could show a reduced yield as the result of reduction in the abundance of the insect. From 1921 the yield decreases steadily to 1923 (5,825 to 2,625 trees), and the natural inference is that the abundance of the insect is similarly decreasing. A scrutiny of the distribution maps Nos. 6 to 8, and, in particular, the course of the 5-tree and 10-tree contours, suggests another inference. In 1920 the number of compartments within the 5-tree contour is 37, equivalent to an area of 2,180 acres; and the number within the 10-tree contour is 24, equivalent to an area of 1,334 acres. In 1921 these territories have enlarged, and a further increase occurs in 1922, while in 1923 a decrease commences. The table below compares the areas having an attack of one tree per two acres and per one acre with the rainfall per annum.

Comparison of borer-territory and rainfall, Thano.

Year.	1920.	1921.	1922.	1923.
No. of compartments with 1 tree per 2 acres	37	47	60	33
Area of compartments in acres . . .	2,180	2,818	3,630	2,075
No of compartments with 1 tree or more per 1 acre.	24	28	23	11
Area of compartments in acres . .	1,344	1,652	1,350	784
Rainfall in inches	78·49	116·96	121 34	84 92

It is evident from the above that the area of infestation was spreading from 1920 onwards. Over the greater part of the forest the general incidence of attack was rising to the level of one tree per two acres, in spite of the fact that it was being reduced in the heaviest centres. *The insect was on the increase and the epidemic was waxing.* We explain this by reference to two factors, the annual rainfall and the control measures. The rainfall from 1920-1922 was favourable for the increase and dispersal of the insect, just as occurred in the previous phase of 1913-1917, while that of 1923, coupled with the effect of the control measures, was less favourable.

as in 1918*. In the territories of most severe infestation the reduction in incidence is directly due to the removal of attacked trees under the control policy. As has been mentioned above, the increased attack in 1921 in the area surrounding compartments 54—58 is due to the fire introduced by the experiment of the divisional officer. The effects of the fire were removed by 1923.

If the foregoing inferences are correct, it would seem, that the remedial measures applicable to epidemics are not capable of strongly influencing the incidence after it has been reduced to a level of one tree per acre. The climatic control is more powerful. We are justified in relying on assistance from natural factors in years of average and low rainfall, but in a period of exceptionally wet years the adoption of special measures would be advisable. In particular the enumeration of attacked trees should be postponed till as late after December as possible (in the north-west of the United Provinces).

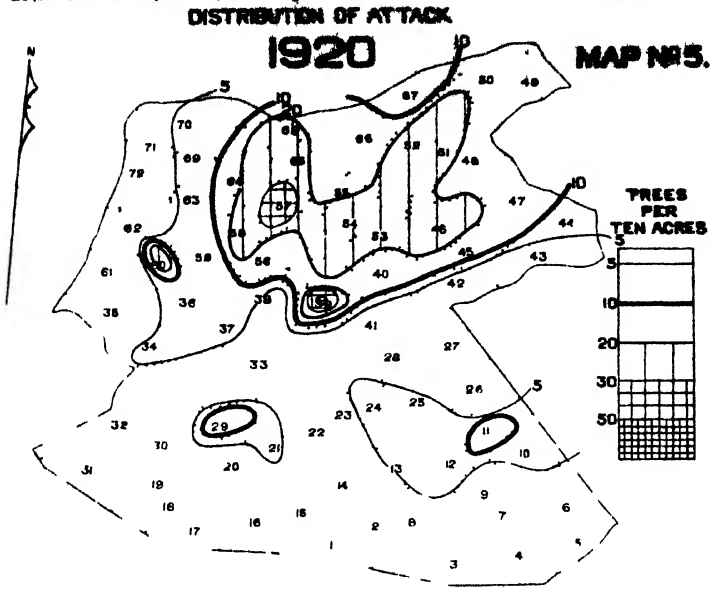
2.—TOPOGRAPHICAL FACTORS IN THE DISTRIBUTION OF THE ATTACK.

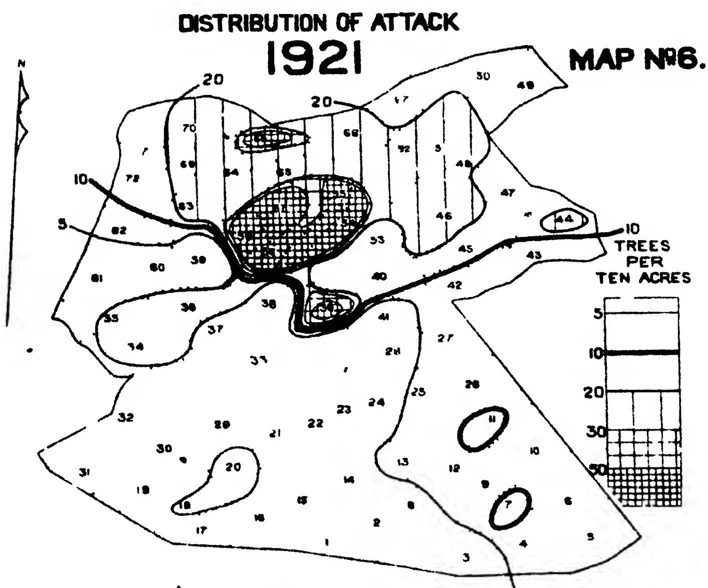
A cursory examination of the distribution maps reveals that the epidemic commenced in the north of the area, and spread south-westwards as it waxed; it retreated to the north-east as it waned, leaving behind horsts or outliers, that gradually broke up or disappeared The country in which it reached its most destructive climax is much dissected by narrow and deep ravines, usually with precipitous banks. Topography of this type may influence the amount of damage by its effect on (a) the breeding-facilities of the insect, and (b) the resistance of the host tree:—

(a) *Breeding-facilities* —In deep shady ravines not only are conditions more favourable for the prolongation of the life of the adult beetles and for egg-production, but also for the successful development of the larvae due to the delayed desiccation of the bark and wood of fallen or felled trees. Moreover, in country cut up by numerous ravines and steepsided valleys extraction is difficult, so that a greater proportion of felling-refuse is abandoned. Hence, ravine country may be considered as forming the endemic foci in the natural habitat of *H. spinicornis* and also as showing the highest degree of attack on living trees in years of low abundance and low rainfall.

(b) *Resistance of the host-tree.*—As Hole has shown [Oecology of *Sal*, Ind. For. Rec. V, IV, (1914) p. 39; (1916) p. 80] the saturated soil of a *sal* forest in the rains developes an injurious factor that may cause the death of the

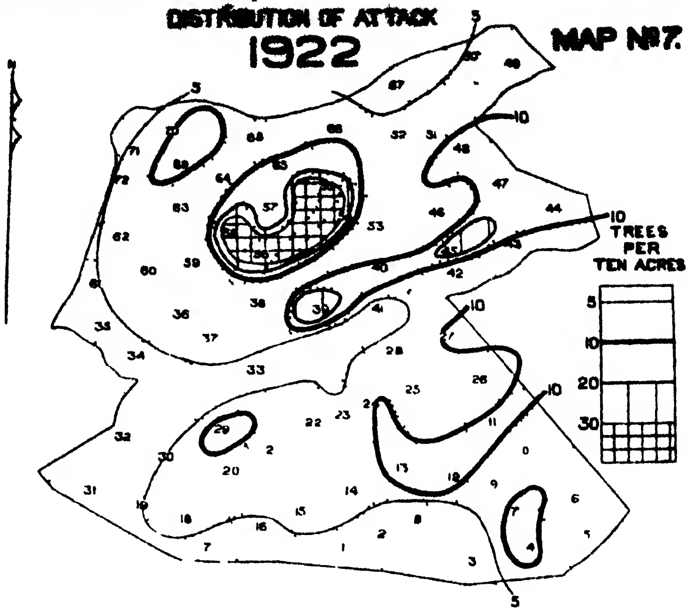
* The evidence as to the effect of rainfall on the abundance of *Hoplocerambyx spinicornis* will be given in another paper. See also page 11.

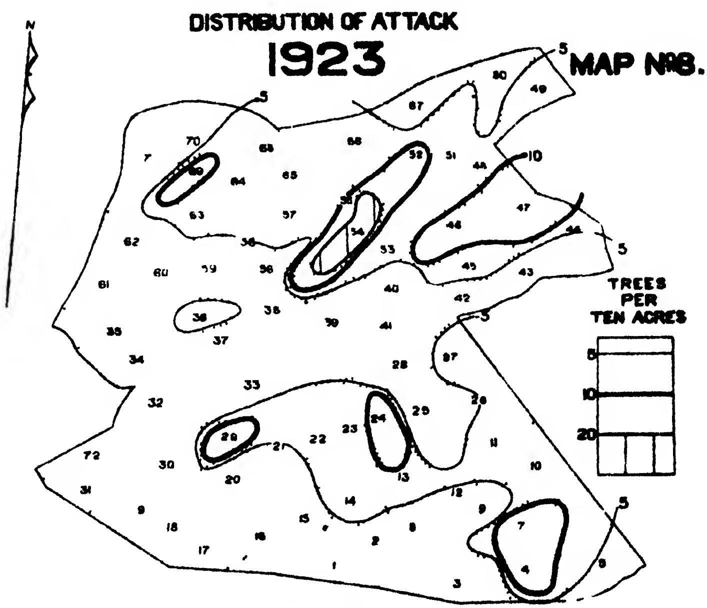




Distribution of attack of *Hoplocerambyx spinicornis* in Thano Working Circle

[Scale—1 Inch to a Mile.]





Distribution of attack of *Hoplocerambyx spinicornis* in Thano Working Circle

[*Scale—1 Inch to a Mile.*]

surface-roots of large trees, and he has pointed out that the death of the deepest feeding roots, particularly of the dominant and most vigorous trees, may be caused by a slight rising of the water-table.

In the loose boulder-deposits on which Thano forest stands it is probable that the latter factor does not occur, although there appears to be evidence of local ponding-up of drainage in the tributary gullies of the main consequent ravines, that have extended their head-waters into the foot-hills. Plane-table surveys of the distribution of attacked trees were made in compartments with topography of this type and also in compartments on level ground in years of high and of low rainfall. The location of the attacked trees was, however, not found to conform very closely with the trend of the stream-courses.

It was equally difficult to ascertain if the former type of injury, *i.e.*, surface water-logging, occurs. The subject has been discussed in a previous paper (Beeson, 1921, Ind. For. pp. 69—76). It was found that in an abnormally wet year (1917) the heaviest mortality occurred in that part of the forest growing on a sandy or gravelly loam, while in an unusually dry year (1918) the mortality decreased on sandy soils and increased relatively on clayey soils. Apparently the better drainage of the sandy and gravelly loams (assisted by the numerous gullies, that are more developed in such areas than in the clayey loams) prevents the formation in normal years of the injurious factor due to bad soil-aeration. A comparison of the proportion of trees killed to trees attacked showed that in an abnormally wet year the resistance to attack of trees of all sizes is about the same, whereas in an abnormally dry year the larger trees are more resistant than the smaller trees. It was assumed that the factor reducing the relative resistance of large trees in a wet year is bad aeration of the surface soil. Since 1920 the slightly attacked trees have not been enumerated and no further evidence bearing on this hypothesis has been available.

8.—THE DISTRIBUTION OF THE ATTACK ON THE GROWING-STOCK.

The general idea, that epidemic attacks of borers of such as the one now described are confined mainly to sickly or over-mature trees, is reflected in the Annual Reports of Forest Administration in the United Provinces for 1916-1917 (page 11), and for 1917-1918 (page 10), where the attacked trees are described as "overmature", "commercially mature", and "hide-bound". That such is not the case is evident from an examination of the figures in the table below, which show the percentage-distribution of attacked trees by girth-classes. As the enumerations from year to year were made sometimes by 1 foot and 1½ feet girth-classes, and sometimes by 4-inch diameter-classes, it has been necessary to lump together

several classes in order to make a direct comparison of percentages over the whole period.

Distribution of attack by girth and diameter classes.

Thano, 1916—1923.

Girth class.	Diameter class.	1916. No. of trees.	1916. Percentage.	1917. No. of trees.	1917. Percentage.	1918. No. of trees.	1918. Percentage.	1920. No. of trees.	1920. Percentage.	1921. No. of trees.	1921. Percentage.	1922. No. of trees.	1922. Percentage.	1923. No. of trees.	1923. Percentage
0'—3' .	0"—12" .	2,529	37	5,175	45	16,094	59	1,831	47	4,048	69	3,031	68	1,755	67
4'—4½' .	12"—18" .	2,643	39	3,808	34	8,236	30	1,376	36	1,[illegible]60	22	1,071	24	655	25
4½'—6' .	18"—24" .	1,254	19	1,904	18	2,585	9	570	15	446	8	291	7	187	7
Over 6' .	Over 24" .	346	5	373	3	565	2	78	2	71	1	33	7	18	1
	TOTALS .	6,772	100	11,440	100	27,480	100	3,855	100	5,825	100	4,411	100	2,625	100

The percentages are shown graphically in the annexed diagram (Fig. 2) which emphasises the fact that the major part of the attack throughout the period has fallen on the smaller diameter classes. With the extension of the epidemic and the increase in the abundance of the beetles from 1916-1918 the severity of the attack on the trees of smaller dimensions gradually increased. During the period of revised control-markings 1920-1923, the distribution of attack has remained remarkably steady, not exceeding 9 per cent. on trees over 4½ feet in girth. The anomalous proportions in the year 1920 appear to be due to the combination of two years' attack (1919 and 1920) in one year's enumeration, the introduction of new marking rules and the date of the enumeration.

The question now arises: Does the percentage-distribution of attack by *Hoplocerambyx* represent a selective action on the part of the beetle by which certain sizes or qualities of *sal* are preferred? A comparison of the distribution of attack with the percentage-distribution of trees by diameter classes in the growing-stock answers this question.

The most recent estimate of the growing-stock in Thano Working Circle (*vide* Working-Plan for Dehra Dun, 1923, page 88A) gives the following figures for *sal*:—

Diameter class.	8"—12".	12"—16".	16"—20".	20"—24".	24" and over.
No. of trees	111,298	65,347	24,531	6,633	2,249
Percentage of total . . .	53	31	12	3	1

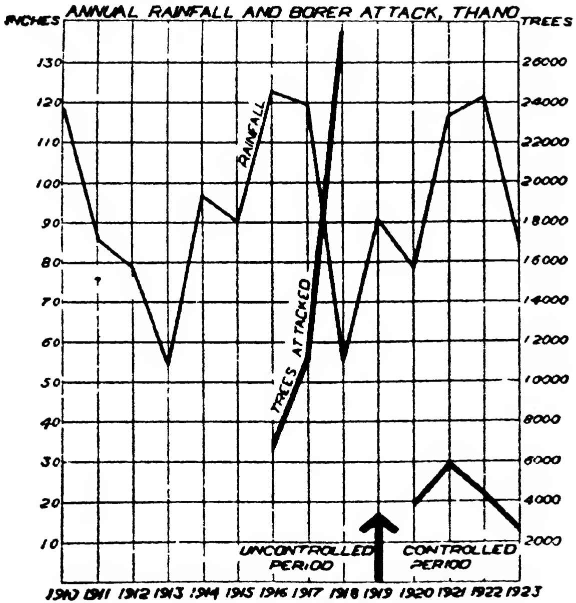


Fig I

Showing the total number of trees marked each year and the rainfall during the calendar year in which the attack occurred.

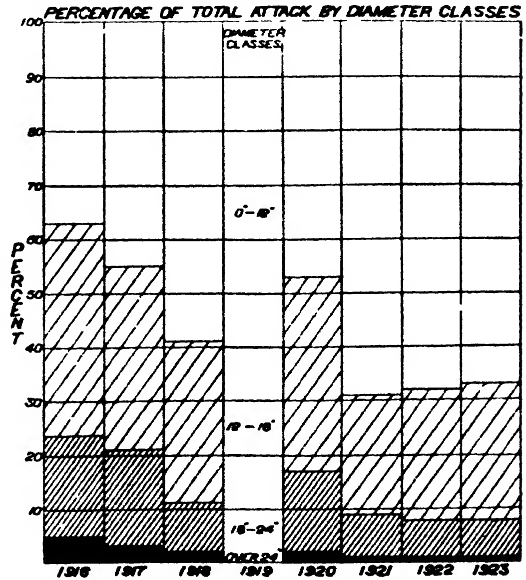


Fig. 2.

Showing the distribution of attacked trees by diameter classes expressed in percentages of the total attack each year.

[To face page 18

Although trees below 8 inches in diameter are omitted from the estimate of the growing-stock, while included in the enumerated attacks, the correlation is sufficient to show that the attack of *Hoplocerambyx* has been primarily proportional to the composition of the growing-stock. A greater number of attacks has occurred on trees of small dimensions because such trees exist in greater numbers.

More accurate comparison is obtainable by adopting the values for 1922-1923 only (when the enumeration of attacked trees was done by 4 inch girth-classes) as in the statement below:—

Percentage of trees in diameter classes.

	8″—12″.	12″—16″.	16″—20″.	20″—24″.	24″ and over.
Growing stock estimate of 1923	53	31	12	3	1
Attacked trees 1922-23, average	56	28	11	4	1

Here a very close agreement is revealed.

This means that the beetle in the last few years of the epidemic has been taking a very evenly-distributed toll of the growing-stock, amounting in 1922 to a mean of 1·49 per cent. and in 1923 to a mean of 0·98 per cent.

The figures immediately below show that the deviations from these means are very slight.

Diameter-class of growing-stock.	8″—12″.	12″—16″.	16″—20″.	20″—24″.	24″ and over	Mean percentage.
Percentage attacks in 1922.	1·45	1·36	1·48	1·70	1·47	1·49
Percentage attacks in 1923.	1·12	0·86	0·81	1·31	0·80	0·98

Hence it is concluded that *liability to attack does not depend on preferences of the beetle, but primarily on the laws of chance.*

NAGSIDH FOREST.—The distribution of attacked trees in Nagsidh Forest in 1921-1922 is as follows:—

Diameter class.	0″—12″.	12″—18″.	18″—24″.	24″ and over.
Percentage of total	59	21	12	8

These quantities are comparable with those for the early years of the epidemic in Thano. No estimate of the growing-stock in Nagsidh by 6″ girth-classes is available for calculation of the proportion the number of attacked trees bears to the number of trees in the stand.

ESTIMATE OF THE LOSS INCURRED.

Before one can estimate if anti-pest operations are profitable, or even justifiable at a loss, it is essential to know the value of the produce endangered, and of the damage incurred or prevented. In the present instance the first essential is a comparison of the values of sound *sal* timber and bored *sal* timber in Thano forest. Unfortunately the systems of sale and purchase of timber in the Dehra Dun division prevailing during the last ten years do not provide data from which the loss due to the attack of *Hoplocerambyx spinicornis* can be calculated with a desirable approach to accuracy. The sale-list of an annual coupe states the numbers of trees of *sal* and of miscellaneous species available with their breast-height girths only. The whole coupe is auctioned standing for a lump sum and in late years, on the monopoly-*cum*-royalty basis also. It is therefore impossible to ascertain the price of *sal* per cubic foot or per tree sound and bored, or even to compare the prices of *sal* and of miscellaneous timbers.

To obtain a basis for a rough estimate of the loss due to the *sal*-borer the control-forms and sale-lists of the division have been scrutinised, and from the obvious errors and discrepancies the more or less reliable data have been extracted. The actual figures are given in Appendix I on pp. 39-44 in some cases after correction of entries that extraneous evidence shows to be wrong. As a basis for comparison the mean price per cubic foot of *sal* timber in a coupe has been taken on the necessary assumptions, that the purchaser is not much influenced by the range in girth of the *sal* or by the miscellaneous species included in the lot. These two factors were, during the period under consideration, not markedly variable.

The volume of stem timber in the round has been calculated according to the following figures:—

Volume of sal *stem timber, Thano.*

Diameter class.	Volume per tree.	Authority.
0"–8"	4 cu ft.	Ind. For. Rec.
Over 8"–12"	7	Working-Plan, Dehra Dun Forest Division, 1923, p. 63.
„ 12"–16"	23	
„ 16"–20"	48	
„ 20"–24"	78	
„ 24"	118	Ind. For. Rec.

For enumerations classified by girth-classes the following figures (obtained graphically) were adopted:—

Volume of sal *stem timber, Thano.*

Girth class	Volume per tree.	Girth class.	Volume per tree.
1'—2' . .	4 cu.ft.	0'—1½'	3 cu.ft
Over 2'—3' . .	6	Over 1½'—3'	5
„ 3'—4' .	20	„ 3'—4½'	25
„ 4'—5' . .	42	...	...
„ 5'—6' . .	70	„ 4½—6'	63
„ 6' . .	118	„ 6'	118

The following table shows the fluctuation in the annual value of (1) *sound*, and (2) *insect-attacked sal* timber in Thano forest:—

Average price of sal *per cubic foot standing.*

Year of sale.	Sound timber.	Attacked timber.	Difference per cubic foot.
	Rs. A. P.	Rs. A. P.	Rs. A. P.
1912	0 6 9	...	..
1913	0 7 10	...	...
1914	0 5 5	...	...
1915 . .	0 4 6	...	...
1916	0 6 1	...	...
1917	0 6 9	0 3 4	0 3 5
1918	0 7 5	0 2 7	0 4 10
1919	0 7 6	0 2 11	0 4 7
1920	0 3 3	0 0 2	0 3 1
1921	0 4 2	0 0 10	0 3 4
1922	0 3 9	0 1 1	0 2 8
1923	0 3 10	0 1 3	0 2 7

Note.—All data are for Thano forest except the figure for sound timber, 1917, which is a mean, and sound timber, 1918 which is for a neighbouring forest.

The Working-Plan, Dehra Dun Division (1923, p. 66) puts the average price of *sal* timber at 4 annas a cubic foot.

Pl. VI., Fig. 3 shows the graphs for the prices per cubic foot of sound and attacked timber and the differences between them.

It is evident that the price of insect-attacked timber varies from the price of sound timber by a fairly constant difference, but is tending to rise in recent years. The drop in price in 1920 is presumably due to the post-war slump.

Using these depreciation factors the annual loss may be estimated as follows:—

Approximate annual loss due to the sal-borer.

Year of sale.	No. of attacked trees.	Volume of attacked trees.	Average loss per cubic foot.	Total loss.	
		Cu.ft.	Rs. A. P.	Rs.	Rs.
1917 . . .	6,772	178,956	0 3 5	38,214	2,68,562
1918 . . .	11,410	286,288	0 4 10	86,483	
1919 . .	27,480	502,221	0 4 7	1,43,865	
1920 . . .	3,855	86,713	0 3 1	16,710	52,318
1921 . . .	5,825	83,692	0 3 4	17,436	
1922 . . .	4,411	67,402	0 2 8	11,233	
1923 . . .	2,625	42,981	0 2 7	6,939	

Pl. VI, Fig. 4 shows the graphs of the numbers of attacked trees sold and the loss in rupees per annum from 1917 to 1923.

In the three years 1917-1919, during which the epidemic spread uncontrolled, the total loss to the Government of the United Provinces due to depreciation of the timber was Rs. 2,68,562 or *Rs. 89,521 per annum* (*=Rs. 17 As. 10 per acre.*)

In the following four years 1920-1923, during which control measures were adopted, the total loss has been reduced to Rs. 52,318 or *Rs. 13,079 per annum.* (*= Rs. 1 As. 6 per acre in the fourth year.*)†

*This result is equivalent to a reduction of 85 per cent.** The extent to which this reduction may be assigned directly to the action of the control-measures can be judged in estimating the loss prevented.

* A calculation similar to the foregoing but made on the average price of a *sal* tree, sound and attacked, irrespective of its volume, gives an annual loss in the first period of Rs. 91,690 per annum, and in the control period of Rs 15,860 per annum.

† LATER NOTE :—The total loss in the fifth year of attack, 1924, was Rs. 4,468 or 14 annas per acre.

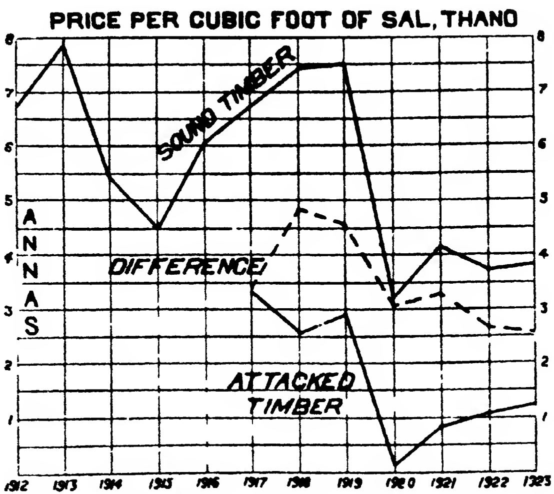


Fig 3.

Comparing the prices per cubic foot of sal timber, sound and attacked, during the years of the epidemic and previously.

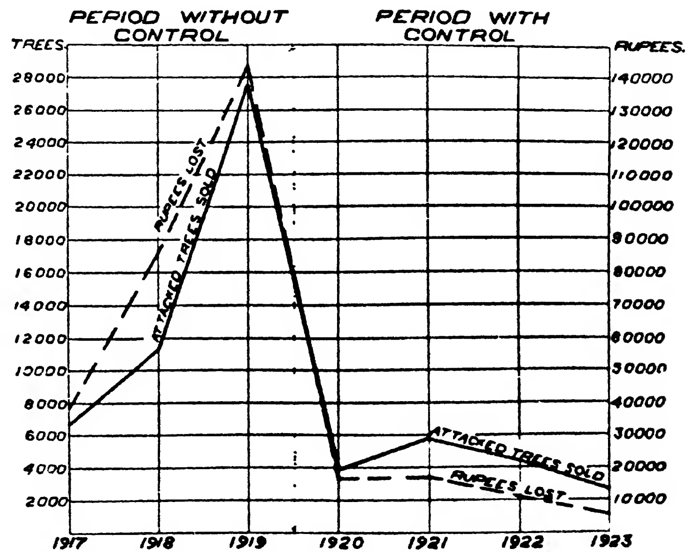


Fig 4.

Comparing the number of attacked trees sold and the loss in rupees each year during the periods without control measures and with control measures.

To face page 22.

ESTIMATE OF THE LOSS PREVENTED.

The outturn of attacked timber in 1917, 1918 and 1919 represents the extent of damage done by the borer during the attacks of the rainy seasons of 1915 to 1918. These attacks occurred unchecked throughout that period and in 1919 also; the extent of the attack in 1919 is unknown, as no enumeration was made, but a large proportion of it was included in the enumeration of the 1920 attack. The full attack of 1920 and of subsequent years is also unknown, as the marking-rules adopted were designed to give a low yield composed of only the most seriously-attacked trees. From 1920 onwards the annual yield of bored trees consisted of part of the current year's and part of the previous year's attack, and the sale of the timber took place in the same season as the marking and felling. Although control-measures are described as having been introduced in the season 1920-21, they could actually have no effect in reducing the abundance of the insect until the season 1921-22. The numerical strength of the insect in the rains of 1921 is the first incidence that is affected by the felling-measures.

The abundance of the borer was theoretically highest in the year 1920 (when the yield of attacked timber was lowest), and from 1921 onwards gradually decreased as a result of the cumulative effect of the remedial measures. Reference to this apparent paradox has been made on page 14.

As it is impossible to separate the incidence data for 1919 and 1920, the year 1920-21 has been included in the period under control-measures, thereby increasing the severity of the test applied to their efficiency. A direct comparison of the three years 1917-1919 with the three years 1921-1923 would be more just to the argument of this report.

In order to demonstrate the efficiency of the control measures, and to answer the question "Does it pay?", it is necessary to consider the probabilities of what might have happened had not the proposed action been taken.

For the purposes of comparison, the normal, unchecked course of the epidemic may be regarded in three phases:—

(*a*) a steady increase in the numerical abundance of the borer at the same rate as that occurring from 1917 to 1919;

(*b*) a maintenance of the incidence at the level reached in 1919;

(*c*) a steady decrease in the numerical abundance of the borer from the level reached in 1919 to that reached in 1923.

All these cases are within the bounds of probability from natural causes, while a fourth case,—the complete and immediate cessation of the epidemic,—is improbable on the facts of the actual incidence in 1923.

Case (a).—The rate of increase in the number of trees marked from 1917 to 1918 is 1·7 and from 1918 to 1919 2·4; mean 2·05. The rate of increase of loss is 2·2 in the first year and 1·7 in the next; mean 1·95. If we assume the loss to be nearly doubled each year it would exceed thirty lakhs in 1923 and the forest would have been seriously depleted.

Case (b).—Assuming the number of trees marked annually to remain steady for the whole period at the level reached in 1919 the loss per annum would be as follows:—

Possible annual loss due to the sal-borer.

Year of sale.	No. of attacked trees.	Volume of attacked trees.	Average loss per cubic foot.	Total loss.
		cu.ft.	As. pies.	Rs.
1920	27,480	502,221	3·1	96,782
1921	27,480	502,221	3·4	1,04,629
1922	27,480	502,221	2·8	83,702
1923	27,480	502,221	2·7	81,087

The total loss for the period would be Rs. 3,66,200; and the loss prevented is Rs. 3,18,882.

Case (c).—Assuming the annual incidence of attack (expressed in the number of trees removed per annum) to have declined steadily from the level of 1919 to the level of 1923, then the annual loss would be as below:—

Year of sale.	No. of attacked trees.	Total loss. Rs.
1920	21,266	92,180
1921	15,052	45,055
1922	8,839	22,509
1923	2,625	6,939

NOTE.—Hypothetical number of trees attacked obtained by proportional reduction from 27,480 to 2,625. Hypothetical loss calculated by proportional increase of actual loss on actual number of trees only, volume not considered.

The total loss for the period would be Rs. 1,66,683; and the loss prevented is therefore Rs. 1,14,365.

Hence, under the most unfavourable conditions for control work, *i.e., supposing the outbreak has died down naturally, the amount saved is over one lakh of rupees.* Moreover, the control-measures have not been carried out at departmental expense; on the contrary the Government of the United Provinces realised Rs. 12,780 as the sale value of the attacked timber standing in the forest. *The profit on the operations is, therefore, not less than Rs. 1,27,145 and lies between that minimum and three lakhs,* or say ten rupees per acre per annum.*

The foregoing discussion shows, we hope, that it pays to adopt remedial measures on a large scale against the heartwood-borer of *sal*, whenever an epidemic occurs, and even when it is optimistically believed, that nature will bring about the same result. That it also pays to follow the same policy for minor outbreaks is illustrated by the operations in the neighbouring forest of Nagsidh

THE CONTROL OF THE SAL BORER IN NAGSIDH FOREST.

In Nagsidh *sal* forest, which is some five miles from the Thano block and is separated by the broad bed of the Song River, trees attacked by *Hoplocerambyx spinicornis* were first noticed in November, 1920. In January, 1921, the attack was reported as serious, and, on enumeration by the Forest Entomologist, some 50 trees were located in coupe 17 and a few more in coupe 18,—sufficient to advise the adoption of remedial measures.

In November, 1921, *i.e.*, after the 1920 beetles had emerged, the forest was enumerated by the division, and 785 freshly attacked *sal* trees were marked, felled, and removed from coupes 9, 17 and 18. They were sold at a flat rate of Re. 1 per tree.

In December, 1922, similar operations yielded 24 trees in coupe 9, which were sold to a contractor for Rs. 50, *i.e.*, Rs. 2 per tree.

In 1923 only 2 freshly attacked trees could be found in coupe 9; these were sold for Rs. 7, *i.e.*, Rs. 3-8-0 per tree, and removed at once.

*The factors controlling the natural abundance of *Hoplocerambyx spinicornis* will be discussed in another paper. It has been discovered that rainfall above the normal annual amount is a factor favourable to the increase of the borer; and as the rains from 1920 onwards have been above the average it is probable that conditions have been favourable for the borer. Hence on this evidence alone the loss prevented is probably near the higher figure. See also page 11 and distribution maps.

The following table shows the losses incurred by borer-attack in Nagsidh:—

Year of sale.	No. of trees attacked.	Volume of trees attacked.	Price of sound sal timber per cubic foot.	Price of insect attacked *sal* timber.	Loss per cubic foot.	Total loss.
		C.ft.	As. pies.	As. pies.	As. pies.	Rs.
1921 . .	785	21,623	2 10	0 8	2 2	2,928
1922 . .	24	577	2 0	1 4	0 8	24
1923 . .	2	148	3 5	0 9	2 8	24

NOTE.—The price of sound timber is based on lump sum and on royalty sales of timber from numerous coupes in the neighbouring blocks.

The control measures have thus been satisfactorily carried out through the agency of contractors at no extra cost to the Province, which realised a profit of Rs. 842 on the sale of the trees.

The argument as to the loss prevented by the measures used in Thano applies equally to this case.

THE CONTROL MEASURES.

To understand the principles on which control measures are based an outline of the life-cycle is necessary.

The Life-Cycle in the Dehra Dun District.—The beetles of *Hoplocerambyx spinicornis* are on the wing from the end of June until the end of September. Eggs are laid during this period and the larvæ tunnel in the sapwood of the tree throughout the rains. With the approach of the cold weather they bore into the heartwood and prepare each a pupal chamber in which the mature larva hibernates. Pupation occurs in spring and the pupal stage lasts for two or three weeks. The immature beetles remain in the pupal chambers until the onset of the rains in June when emergence commences. The generation is thus annual, but the greater part of the damage to the timber is done in the course of a few months before the cold weather.

The Control measures.—The control of the pest is effected by what are logically entirely preventive measures, since there is no

remedy for timber that has been damaged or for a tree that has been fatally attacked. For practical purposes one may consider (1) as *Preventive measures* those of which the object is the maintenance of the damage to felled timber and standing trees at a tolerable degree; and (2) as *Remedial measures* those of which the object is the reduction of abnormal or epidemic damage down to the tolerable degree. The preventive measures should be applied regularly as part of the normal system of management of the forest, whereas the remedial measures are required for exceptional or abnormal conditions. It is self-evident that good silviculture is a preliminary to control measures and that clean utilisation should follow.

PREVENTIVE MEASURES.

1. Removal of the bark of all timber logs that remain on the felling-area or in depôts within or near the forest during the rains following the felling. The latest safe date for the removal of bark coincides with that of the commencement of the monsoon rains.

2. Removal of the bark of all branch-wood, butts, forks, etc., constituting felling-refuse down to 8 inches diameter, as soon as possible after felling.

3. The use of trap-trees (*a*) and the adoption of girdling (instead of felling coupes) (*b*) are alternative preventive measures, but no investigations have been made as to their relative cost compared with those of 1 and 2.

NOTE. The necessity for preventive measures depends on the liability of the locality to permanent annual damage, which will vary within the limits of a division. It is obvious that the reputation of coupes or smaller units of area should be ascertained and the endemic foci or breeding centres of the borer should be located before the necessity for prevention is accepted over the whole division. The special surveys that are suggested on page 36 should provide the required information.

REMEDIAL MEASURES.

1. Early detection of attacks on small groups or isolated trees.

2. Enumeration of attacked trees at the close of the rains preferably in December (in Dehra Dun).

3. Felling and removal from the forest of all parts of the tree down to 8 inches diameter before the commencement of the rains of the following calendar year.

4. Removal of all parts of the tree down to 5 inches diameter in years of exceptionally high rainfall.

5. (i) Trees to be removed have the following characteristics:—
   (*a*) Dead or dying trees with the foliage fallen or turning brown.
   (*b*) Trees with green foliage and an abundant ejection of wood-dust (*vide* plate VII, figs. 1—5).*

   (ii) Trees to be left in the forest have the following characteristics:—
   (*c*) Trees with green foliage and an appreciable outflow of resin or dammar.
   (*d*) Trees with green foliage and a small ejection of wood-dust, *i.e.*, not forming a definite heap at the base of the tree.*

   (iii) Trees to be removed or left at discretion are:—
   (*e*) Trees more than twelve months dead, *i.e.*, with dry or fallen bark and rotting sapwood.

6. Repetition of the operations in subsequent years in all areas where the infestation is greater than one per cent. of the growing stock (or alternately one tree per acre).

THE FELLING OF TRAP TREES AS A CONTROL MEASURE.

A well-known principle in the control of bark-breeding insects exists in the felling of living trees at an appropriate period to act as traps. The insects concentrate their efforts on the more favourable material provided in the freshly-felled trees and neglect the standing crop that it is desired to protect. Before the development of the borers is completed the trap-trees are destroyed or removed. The Chief Conservator of the United Provinces advocated this method in 1918, on the assumption that the standing attacked trees of the season 1917-18 contained a sufficiently large proportion of weakly infested trees to provide breeding-material for the whole population of beetles. As mentioned on page 5 the senior author suggested that the results would not be satisfactory, as the actual rate of increase of the beetle was greater than that corresponding to the available breeding-material; but this advice was disregarded.

*The photographs on plate VII show heavily attacked trees with an abundant ejection of wood-dust. In cases of less severe attack the amount of wood-dust may not amount to more than a few handfuls; such trees should be felled if the dust is accumulated in one spot in a heap, or rejected if the dust is scattered. A sharp line of definition cannot be drawn between cases (*b*) and (*d*). Our check surveys show that in practice the error due to faulty selection is not serious. The errors due to careless enumeration are greater. The subsequent checks on the annual enumerations showed the following deficiencies:—

(*a*) Trees that should have been selected but were omitted—in 1918 4 per cent.; in 1920 110 per cent.; in 1921 37 per cent.; in 1922 9 per cent.; in 1923 24 per cent.

(*b*) Trees that should have been removed by contractors but were abandoned—in 1919 7 per cent; in 1921 16 per cent.; in 1922 7 per cent.; in 1923 8 per cent.

These errors were not rectified but nevertheless the pest was successfully controlled.

Fig 1.

Fig 2.

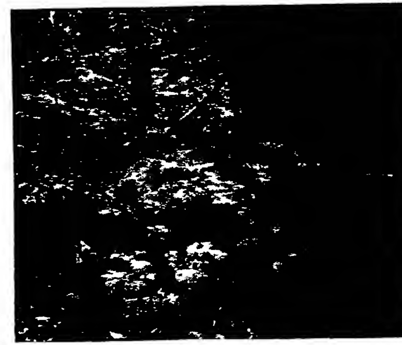


Fig 3.

Fig 4.

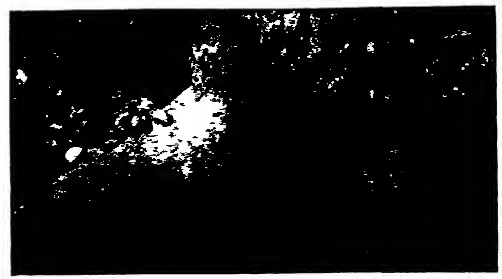


Fig 5.

Living *sal* trees attacked by *Hoplocerambyx spinicornis*, showing the quantity of wood-dust ejected in cases of heavy infestation. (The axe against the base of the tree indicates the relative size of the heap of wood-dust).

Sample plots.—In 1918 seven compartments were selected for maintenance as permanent sample plots, having a total area of 506 acres, *viz.*:

Compartment No.	Area acres.	Compartment No.	Area acres.
11	59	24	76
14	65	25	74
22	80	26	64
23	88	Total	506

Later it transpired that the area selected was one of low incidence, but it is probable that the conditions observed occur proportionately in areas of high incidence.

THE PROPORTION OF ATTACKED TREES THAT ARE RE-ATTACKED.

1918: In October-November, 1918, compartments 11 and 22 were plane-table surveyed, and all standing attacked trees (classified as slight, moderate and heavily attacked) together with the stumps of the felled trees of previous years' attacks were mapped. In March, 1919, and again in August-September, 1919, the two areas were re-surveyed; the freshly infested trees were added to the map, and the re-attacked stumps were enumerated. The re-attacks discovered on the stumps were taken as evidence of re-attack on the marked trees while standing, as between the two surveys these trees were felled and exported.

The distribution of the attack of the 1919 beetles (*a*) on previously attacked trees as represented by stumps, and (*b*) on trees hitherto unattacked is given below —

Proportion of trees re-attacked in 1918.

Compartment No.	TREES MARKED AS ATTACKED IN		STUMPS FOUND TO SHOW RE-ATTACK.
	1917.	1918.	In 1918.
11	266 (including 87 trees damaged by previous fellings.	1094	100
22	145 (including 16 trees damaged by previous fellings).	92	35

Thus the percentage of trees showing re-attack was 88 in compartment 11, and 24 in compartment 22; and the proportion of attacks on new trees to the total attack was in the first plot 83 per cent., and in the second 72 per cent.

From which it may be concluded that the trees felled and left to act as traps did not absorb more than 17—28 per cent. of the next year's attack.

1919: In order to obtain more accurate information as to the extent that felled trees can act as traps, observations were made over the whole 506 acres in the following year. In the sample plot area the following operations were carried out:—

1. All the trees of the attack of 1918-19 were felled in the cold weather and left in the forest, until the spring of 1920.
2. In compartments 14 and 23 all the heavily attacked trees were felled and removed from the forest in April-May 1919
3. From compartments 24 and 25 the heavily attacked trees were removed only partially in May 1919 (owing to failure of the labour-supply).
4. From compartments 11, 22 and 26 none of the heavily attacked trees were removed in 1919 (but a few were felled and logged).
5. All compartments were specially enumerated in October, 1918, March, August, September, 1919 and September 1920.

The results of these operations are compared in the following table:—

Proportion of trees re-attacked in 1919 and 1920.

Compartment group.	Number of trees slightly or moderately attacked in October, 1918.	Number of trees re-attacked in September, 1919.	Number of trees re-attacked in September, 1920.	Treatment of heavily attacked trees in 1918-19.
11,22,26	1201	106 (8·3 %)	4 (3·7%)	None removed.
24,25	190	6 (3·1 %)	...	Partially removed
14,23	79	...	...	Wholly removed.

The experiment thus demonstrated that the proportion of felled or standing attacked trees, that is re-attacked in subsequent years, is small enough to be negligible as a factor in checking the increase of the beetle. It also demonstrated that the complete removal of heavily attacked trees prevents re attacks entirely.

OCCURRENCE OF RE-ATTACKS UNDER NATURAL CONDITIONS.

Until the season of 1919 it had been assumed that a green standing *sal* tree attacked by *Hoplocerambyx* was either killed outright in one season, or else survived the initial onslaught by drowning out all the *Hoplocerambyx* larvæ,—or at any rate a large proportion of them.

In 1919-1920 analyses of attacked trees were made by the junior author to determine the extent to which trees escaping death in the first attack were liable to be re-attacked in subsequent years. The trees were each cut into short billets, which were split and worked up with axe and chisel, so that each pupal cell was located and dated. Thirty trees were analysed, one of which has been rejected in the data given below.

Slightly attacked trees.—Eleven trees, out of the thirty, ranging in girth from 1 ft. 4 ins. to 3 ft. 5 ins. were felled and analysed in October, 1919, and April, May, 1920. These trees had been classified as "slightly attacked" in 1918, and had not died subsequently. Each tree showed the larval work of 1918, that had failed in its early stages owing to the reaction of the tree. There were no subsequent attacks in 1919.

Heavily and moderately attacked trees.—Nineteen trees ranging in girth from 1 ft. 11 ins. to 4 ft. 7 ins. that had been classified on enumeration as 'moderate', 'heavy' or 'dry' were analysed at various dates. The age and distribution of the attack on each tree is given in the tables below.

Eight of the trees showed attack in one year only, the attack being fatal—

Girth of tree.	Nature of attack observed in 1918.	Date of analyses.	NO. OF PUPAL CHAMBERS INDICATING ATTACK IN YEAR		
			1917.	1918.	1919.
ft. ins.					
1·11	Dry . . .	October 1919	87	...	...
3·7	Heavy . .	„	...	128	...
4·7	„ . .	December 1919	...	86	...
4·0	Dry . . .	„	...	54	...
3·5	Heavy . .	„	...	41	...
3·2	Dry . . .	April 1920 .	...	31	...
3·7	Heavy . .	December 1919	...	29	...
4·7	Dry . .	„	...	26	...

The remaining ten trees gave evidence of having been attacked 2 or 3 years running. In the table below the intensity of attack is expressed by the percentage of the total number of complete pupal chambers per tree assigned to each year.

Girth of tree.	Nature of attack observed in 1918.	Date of analyses.	Total No of pupal chambers	Percentage of pupal chambers indicating attack in year		
				1917.	1918.	1919.
ft. ins						
2·6	Moderate .	April 1920 .	7	...	86	14
4·0	Dry . .	„ .	204	70	26	4
4·3	Heavy	September 1919	217	58	41	1
2 1	Dry . .	October 1919 .	96	57	43	...
3·5	Heavy .	September 1919	147	51	46	3
3·8	Moderate .	March 1919	25	40	60	..
3 9	Heavy	October 1919	63	30	68	2
3·10	„	March 1919	153	21	79	..
2·10	„ .	October 1919	32	16	84	...
4·7	„ .	December 1919	94	...	3	97

In most of the cases recorded in the above table the heavy primary attack, that killed the tree, left portions of the bark untraversed by larval galleries in sufficient amount to support numerous individuals in the following year. Taking the eight trees attacked in 1917, it is found that they supported 464 individuals in 1917 and 455 individuals in 1918. (In both cases no account is taken of individual larvæ that failed to reach maturity and prepare a closed pupal chamber. A tree may be heavily attacked and nevertheless reveal on analysis very few pupal chambers, if the majority of the larvæ is killed off before maturity by parasites, disease, etc.).

If the rate of increase of the beetle were unity and the proportion of slightly attacked trees in the enumeration were not less than half, then the felling of the whole yield should *theoretically* supply sufficient breeding-material to accommodate the whole of the emerging beetles.

The failure of this method of control, *in practice*, seems to us to be due to two main causes, (*a*) the rate of increase of the beetle was about x 2; and (*b*) the trees were felled in the course of the cold weather, so that by July they had dried out and lost their attractiveness.

THE BURNING OF FELLING REFUSE AS A CONTROL MEASURE.

The fundamental principle of the control measures for *Hoplocerambyx spinicornis* is the removal of felling-refuse at the close of felling-operations before the emergence of the beetles. If the removal of breeding-material cannot be effected by enforcing the relevant clauses in the purchasers' agreements, the burning of same by the departmental agency is necessitated. But the remedy may be worse than the disease, if the burning is not carried out cautiously. The injurious results of careless burning are illustrated by the experiment of 1921 in compartments 54 to 58, in which the standing trees were so severely damaged, that they succumbed more easily to the attacks of the borer in the following season. The burned area apparently acted as a centre of attraction to the swarming beetles, so that the infestation of the surrounding forest was also increased, though much less heavily.

The attack per acre for the years 1920-1923 in compartments 54-58, covering an area of 280 acres, is compared below with the attack in compartments 38-40, 46, 51-53, 59, 63-66, which form a zone of 636 acres immediately surrounding them.

Compartments.	Area in acres	Average number of attacked trees per acre in years			
		1920.	1921.	1922.	1923.
54, 55, 56, 57, 58	280	2·5	6·56	3·38	1·09
38, 39, 40, 46, 51, 52, 53, 59, 63, 64, 65, 66.	636	1·93	2 28	1·04	0·72

The burning of felling-debris ordinarily cannot be attempted until extraction work has ceased in the coupe, *i e.*, until April or May, when a ground-fire is likely to be destructive to the standing crop. It is however unnecessary to burn small branch-wood below 4" diameter, chips, slabs and bark. The important breeding-material is in the form of branch and stem-wood well over 4" in diameter, *e.g*, forked pieces, butt-ends, hollow or curved logs, etc., rejected by the timber-contractor. These should be removed to an open space such as a *khal*, *nullah*, road, or blank, and there stacked and scorched with a light brushwood-fire. It is evidently a wise insurance to incur the cost of collecting and dumping felling-refuse from areas, where an uncontrolled fire will cause greater loss.

THE ANNUAL LOSS IN THE *SAL* FORESTS OF INDIA.

Fourteen years ago the total annual outturn of *sal* timber from all sources in India (including Nepal) was estimated at 8,120,551 cubic feet* or 180,434 tons (Pearson, 1913, Ind. For. Mem. II, ii). We have been unable to secure figures showing the present day outturn of *sal* from every one of Government forests, native states, zemindari and private lands, but from the data available it is evident that there has been an appreciable increase. The following statement compares the outturn for the year 1910-11 with the average of the annual outturn of the period 1919-20 to 1923-24.

The total annual outturn of sal.

Department.	Outturn for 1910-11. cu.ft.	Average annual outturn for 1919-20 to 1923-24. cu.ft.
United Provinces	3,617,145	4,428,800
Bengal	1,252,499	937,708
Bihar and Orissa	694,400	1,395,109
Assam	514,720	641,358
Central Provinces	196,132	1,150,469
Madras	61,539	947,000
Punjab	1,301	?
Orissa Feudatory States (22)	966,764	23,778
Central Provinces States	50,000	188,478
Mechpara Estate, Bengal	337,647	308,526

Applying this rate of increase the total annual outturn of *sal* timber from all sources at the present time may be placed at about 12,000,000 cubic feet (or 245,000 tons), of which Government forests produce not less than 9,500,000 cubic feet.

Of this outturn part is "dry" timber. The proportion of dry timber in a forest may be taken as an index of conditions which favour the incidence of boring insects and the production of borer-damaged timber. Various causes bring about the death of *sal* trees, but very few of them preclude attack by borers afterwards. In moist forests nearly every dead tree is attacked by *Hoplocerambyx*, while in drier localities desiccation of the bark may be so rapid that the

* *Note.*—There is a discrepancy in the statement of page 70 of the Memoir cited the figures for Mechpara Estate given on page 61 differ from those on page 70. Applying the former the total outturn of *sal* in 1910-11 should be 8,345,875 cu.ft.

timber more often escapes. Local variation in climatic conditions from year to year causes fluctuations in the severity of dying-off and of borer-attack; in forests in which *Hoplocerambyx* is endemic, the incidence of borer-attack rarely drops below 1 per cent. of the growing-stock, and may rise to over 30 per cent. without attracting the notice of the divisional forest officer (as the analysis of any related series of annual yields will show).

Fourteen years ago about 3,000,000 cubic feet, or 47 per cent. of *sal* timber extracted from Government forests was classed as dry. At the present time the records of dry timber are maintained very irregularly and all provinces cannot supply actual figures for the proportion of dry wood in the total yield of the last five years. From many sources no information is available. Below is given a comparison of the percentage of dry *sal* in the total yield of 1910-11 with that of the average yield of 1919-20 to 1923-24.

The proportion of dry sal *in the total outturn.*

Department.	Percentage of dry *sal* in yield of 1910-11 (actual returns).	Department.	Average annual percentage of dry *sal* in yield of 1919-20 to 1923-24	
United Provinces	51	United Provinces		
		Western Circle	5	Estimated by C. F.
		Eastern Circle	4	
Bengal	60	Darjeeling	1	Actuals.
		Kalimpong	6	
		Kurseong	30	
		Buxa	33	
		Jalpaiguri	38	
Madras	85	Ganjam	8	Estimated by D. F. O.
Bihar and Orissa	20	Bihar and Orissa	17	Actuals.
		Orissa Feudatory States (22).	34	Actuals.
		C. P. Feudatory States.		
		Raigarh	0·2	Actuals.
		Sarangarh	10	Estimated.
		Mechpara Estate	40	Actuals.
All Government forests	47			

These figures suggest that the outturn of dry wood nowadays is much less than it was in 1911. There is, however, an unknown

but large quantity of dry and borer-damaged wood, that is either not removed at all or is not distinguished in the annual sale lists and control forms. Thano forest itself affords an illustration of the amount of borer-damaged timber that may be classified as green. According to the provincial estimate the outturn of dry *sal* timber from the whole of the Western Circle, United Provinces, for the period 1919-20 to 1923-24 is 494,800 cubic feet (or 5 per cent. of the total outturn). The yield of attacked timber from Thano *alone* in the years 1919-23 amounts to 783,009 cubic feet (or 8 per cent. of the total outturn for the circle) of which, however, 86 per cent. was classified as "green". In illustration of the local variation of the percentage of *sal* classed as dry, the 22 Feudatory States of Orissa may be cited. On the average of the last five years there is a range of 0·4 per cent. to 88 per cent.

In taking "dry" *sal* timber as an index of the prevalence of *Hoplocerambyx* attack, it is probable that in most cases the importance of the pest will be under-estimated. Nevertheless there is sufficient indication that the arbitrary tax of 10 per cent., usually applied in assessing recurrent annual damage by insects, is not excessive. The 10 per cent. ratio may be safely adopted in establishing the economic importance of *Hoplocerambyx spinicornis*.

The quantity of *sal* timber, converted and in the round, from all sources in India, that is damaged each year by the heart-wood borer may therefore be placed at over 1,200,000 cubic feet of which 950,000 cubic feet is produced in Government forests. At an average depreciation of 4 annas per cubic foot* *the annual loss on sal timber extracted from State forests amounts to Rs 2,37,500.* This estimate leaves out of consideration the total loss on trees so severely damaged that their extraction is unprofitable.

PREVENTION OF THE ANNUAL LOSS

The annual loss of dry timber and unextracted timber is preventable; and the measures for its prevention exist in the prescriptions of the working-plans, that authorise dry wood or unregulated fellings. As now instituted such fellings, like other similar silvicultural operations, have no value as protective measures because (*a*) the intervals at which they recur are too long, and (*b*) the felling or extraction of the selected trees does not take place until the season following the marking.

Protection may be assured by the adoption of the following principles:—*Sal* forests, which remain unworked for more than five years, should be surveyed in the autumn or winter for dead and insect-attacked trees which should be cut out and removed *before the*

*The figures obtained for Thano for the depreciation in the value of standing timber are applied in default of other data.

following rains. Fellings should continue in the following and subsequent years in those localities where the infestation is higher than one per cent. of the growing-stock (or alternatively one tree per acre)

Except in unusually remote forests these operations should pay for themselves and at their commencement a considerable revenue should accrue from the accumulated "dry" trees of the rest period The main object of subsidiary fellings of this nature is the reduction of the proportion of borer-damaged timber in the regular coupes and the consequent improvement in the reputation of the forest

At the moderate estimate of a 10 per cent. depreciation the *sal* forests of the United Provinces (with an outturn of 4,500,000 cubic feet), might be expected to yield an increased revenue of Rs 1,12,500 or nearly two annas per acre per annum.

For forests such as those of Bengal or Bihar and Orissa with a present high depreciation percentage an increased revenue of Rs. 70,000 is to be anticipated.

It should be evident, that it is worth while recording the proportion of dry wood in the annual coupes in all *sal* forests, and that in many divisions the institution of short-cycle protective fellings would be profitable.

Later Note.

While correcting the proofs the figures for the attack of 1924 have been collected. The total number of trees attacked in the Thano forest, compartments 1-76. was 1,438, having a volume of 32,960 cubic feet. The timber was sold for Rs. 8,797. The sale price of attacked *sal* was as 1 pies 10 per cubic foot (or 7 pies higher than in the previous year). The total loss incurred was Rs. 4,468 or 14 annas per acre.

In only 5 compartments out of 76 was the attack higher than one tree per acre; the average for the whole forest being 0·28 trees per acre. This represents an incidence that would of necessity be regarded as a tolerable degree of loss in most *sal* forests.

SUMMARY.

In 1916 an epidemic outbreak of *Hoplocerambyx spinicornis* was discovered in the forests of *Shorea robusta* in Dehra Dun Division, United Provinces. The affected area extended over nearly eight square miles of forest. Trees of all sizes and ages were attacked and killed, but the distribution of the attack was closely in direct proportion to the constitution of the growing-stock. The epidemic ran on unchecked for four years and during that period the timber damaged by the borer amounted to nearly a million cubic feet (45,692 trees) representing a loss of Rs. 2,68,500.

Control measures were adopted in the working season 1920-21 and have been applied annually since then. During the four years of the period under control measures the total quantity of timber damaged has been 280,788 cubic feet (16,716 trees) representing a loss of Rs. 52,318. The average annual loss has been reduced from Rs. 89,521 per annum to Rs. 6,939 in the fourth year. The epidemic has been successfully fought as the incidence of attack has been reduced to less than one per cent. of the growing-stock. It is estimated that the loss prevented lies between one and four lakhs.

The origin of the epidemic is discussed and fellings, frost, and the health of the forest are rejected as possible contributory causes. It is considered that a series of years of abnormally high rainfall is the main predisposing cause. Maps have been prepared showing the topographical distribution of the attack and its intensity year by year, which reveal an extension of the borer-infested territory coincident with rainfall above the average, even in the period during which the control measures operated.

An estimate is attempted of the economic importance of the *sal* borer in other parts of India. Based on records of the proportion of dry timber in the total outturn it is considered that at least 1,200,000 cubic feet of *sal* timber is damaged annually in India. This represents a loss in Government forests alone of over two and a third lakhs of rupees.

Control measures are described for use as remedies against epidemic outbreaks, and for regular application in the prevention of excessive annual damage. In principle these measures are applicable throughout the *sal* habitat, but require simple inexpensive local experiments to adjust them accurately to the varied climatic conditions of different forest divisions.

NOTE.—A more detailed summary has been published in the *Indian Forester*, Vol. L (1924), pp 516—524.

APPENDIX I.

Statement showing total number of sal *trees felled in experimental working circle, Thano Forests, Dehra Dun Division, U. P., under cultural operations, etc., and due to* Hoplocerambyx spinicornis *attack from 1910-11 to 1923-24; and the prices realised.*

Year.	Periodic block or compartment.	Working plan prescriptions.	Total *sal* trees, all classes, as per control form of the Division.	Total *sal* trees, all classes, as per sale list of the Division.	Prices realised as per sale list.	REMARKS.
					Rs.	
1910-11	P. B. I. cp. VIII—Ramnagar block	Uniform fellings	474	657	.	
	P. B. II, III, V, VI, cp. VIII—Lambi Rau block	Selection fellings	183	...	...	
	Ramnagar block	Unregulated (removal of dry wood).	1,775	1,788		
	Whole except VII to IX—Lambi Rau block	Ditto	37	...	...	
	Ditto	Unregulated (green trees)	1	...	...	
1911-12	Compartments 3, 9 in part	Regeneration felling	655	655	...	
	" 4, 5, 6, 7	Sel. cum. improvement	896	896	...	
	Compartment lines	Unregulated	815	...	...	
	" 43*	"	288	1,225		*Sylviculturist's sampleplot.
	" 32	"	128	...		
		" (removal of dry wood).	17	...	...	

APPENDIX I.

Statement showing total number of sal *trees, etc.*—contd.

Year.	Periodic block or compartment.	Working plan prescriptions.	Total *sal* trees, all classes, as per control form of the Division.	Total *sal* trees, all classes, as per sale list of the Division.	Prices realised as per sale list.	Remarks.
					Rs.	
1912-13 .	Compartments *6, 7, 18 .	Regeneration felling .	3,302	3,314	43,000	
	,, 14, 5	Sel cum. improvement .	1,798	1,925	14,200	
	Coupe VIII . . .	Cleanings . . .	70	...	.	Prescribed for 1911-12.
	Compartments 4, 5, 6, 7 (P. B. IV).	,, . .	896	...	...	Ditto.
	Whole circle .	Unregulated (removal of dry wood).	410	739	2,200	
	Ditto . .	Ditto .	49	...	...	
	Compartments 43 – 46	Unregulated . .	383	...	...	For F. R. I.
1913-14 .	Compartments 19, 20, 29 .	Regeneration felling .	3,914	4,249	59,500	
	,, 21, 22 .	Sel. cum. improvement	1,712	1,825	10,000	
	,, 34*	Ditto	62	...	..	*Prescribed for 1914-15.
	Compartment lines of 24, 25, 17, 48.	Unregulated . .	73	...	...	
	Compartments 11, 12, 19, 20 and 29.	Unregulated (removal of dry wood) .	33	...	...	
	,,	*Insect attack*	52	...	...	
	Whole circle† . . .	Unregulated . . .	85	...	...	†For Government.

1914-15	Compartment 30	Regeneration felling	1,280	1,328	20,800	
	„ 31	Sel. cum. improvement	738	753	2,400	
	„ 32	„ „	1,596	1,823	4,900	
	Compartments 33, 34	„ „	2,286	2,515	3,310	
	„ 30, 31, 32, 42, 43, 44, 47.	Unregulated (removal of dry wood).	22	...	...	
1915-16	Compartment 1	Regeneration felling	1,330	1,238	10,500	
	„ 23	Sel. cum. improvement	1,774	1,717	3,200	
	„ 24	„ „	825	963	2,250	
	Compartments 54, 55, 68	Unregulated (removal of dry wood).	138	...	..	
	„ 43, 44	„ „ „	28	136	200	
1916-17	Compartment 2	Regeneration felling	1,656	...	...	
	„ 1*	„ „	59	1,765	26,000	* Prescribed for 1915-16.
	Compartments 27, 28	Sel. cum. improvement	12,112	1,783	12,200	
	„ 41, 42	„ „	741	836	3,500	
	„ 25, 26†	„ „	2,023	2,136	12,050	† Prescribed for 1915-16.
	„ lines of 39, 40	Unregulated	65	65	150	
	„ „ „ 6, 10, 27	„	158	...	...	
	„ „ „ 43, 44, 47, 68.	„	85	...	...	
	Compartments lines of 25, 26	„	4	...	...	
1917-18	Compartments 3—7 and 9—33.	*Insect attack (1916)*	*1,047*	*1,427*	*7,200*	‡ There is no record either in the control form or list of produce of the division of the 1,113 trees felled by the Silviculturist for sample plots.
	Compartments 34—53	„ „ „	*3,514*	*2,686*	...	
	Compartment 43	Sel. cum. improvement	...	520	22,100	
	„ 54—72	*Insect attack (1916)*	*1,720*	*2,298*	*7,800*	
	„ 1—33; 34—47; 48—72.	*Insect attack (1917)*	*11,336*	...	...	
	Compartments 27, 28, 43, 44, 46, 47.‡	Unregulated§	1,113	...	...	§ For Silviculturist's sample plots.

APPENDIX I.

Statement showing total number of sal *trees, etc.*—contd.

Year.	Periodic block or compartment.	Working plan prescriptions.	Total *sal* trees, all classes, as per control form of the Division.	Total *sal* trees, all classes, as per sale list of the Division.	Prices realised as per sale list.	REMARKS.
				..	Rs.	
1918-19	Compartments 1 - 72	*Insect attack* (1918)	24,152	(1917) 2,364 (1917) 4,144 (1917) 3,930	9,000 17,000 17,600	
1919-20	Compartment 8	Regeneration felling	3,056*	4,320	27,000	Prescribed for 1917-18.
	" 9	" "	2,239*	2,354	33,000	Prescribed for 1918-19.
	Compartments 10, 11, 12	Sel. cum. improvement	3,467*	6,123	66,000	Ditto.
	" 44, 46, 47	" "	3,654*	5,566	34,000	Prescribed for 1917-18.
	Compartment 64	" "	1,167*	1,749	25,200	Prescribed for 1923-24.
	Compartments 1, 3—7, 15—17.	*Insect attack*	10	(1918) 2,165	11,000	*Includes insect attacked trees also.
	Compartments 18—21, 27—33, 41 - 43.	" "	29	(1918) 4,173	13,500	
	Compartments 34—40, 45, 48—53.	" "	51	(1918) 9,259	38,500	
	Compartments 54—63, 65—72	" "	28	(1918) 7,923	14,210	
	" 11, 22, 42, 44, 47.	Unregulated (removal of dry wood).	20	...	...	

		Unregulated—				
	†Compartments 14, 23, 24, 25.	*Insect attack*	...	*147*	...	†Removed to Lachiwala by F. Z.
	† „ 11	„ „	...	*12*	...	Removed to Insectary by F. Z.
	† „ 11, 22, 23, 41, 44.	„ „	...	*25*	...	Felled by F. Z. for purpose of analysis. No record in control form or list of produce of the division.
1920-21	Compartment 13	Sel. cum. improvement	1,127	††1,736	1,500	††Includes insect attacked trees also.
	„ 39, 40, 45, 53	„ „	4,654	7,591	25,400	
	„ 64	„ „	569	582	600	
	„ 8, 9	Cultural operation	24	...	...	
	„ 10, 11, 12	„ „	190	...	...	
	„ 44, 46, 47	„ „	302	...	...	
	Whole circle	Unregulated— *Insect attack* (1920)	‡‡*2,611*	*3,855*	*975*	‡‡Not given in the list of produce of the division; figures from F. Z.'s enumeration list.
	„ 22	*Insect attack*	...	§§*5*	...	§§Felled by F. Z. for purpose of analysis.
1921-22	Compartment 13	Sel. cum. improvement	378	...	...	
	„ 39, 40, 45, 53	„ „	350	...	...	
	„ 16	Regeneration felling	1,160	1,569	11,000	
	„ 10, 11, 12	Cultural operation	4	...	...	
		Unregulated (removal of dry wood).	26	...	...	
	Whole circle	*Insect attack* (1921)	*4,716*	‖‖*5,821*	*4,456*	‖‖Not given in the list of produce of the division. Figures from enumeration list.

APPENDIX I.

Statement showing total number of sal *trees, etc.*—concld.

Year.	Periodic block or compartment.	Working plan prescriptions.	Total *sal* trees, all classes, as per control form of the Division.	Total *sal* trees, all classes, as per sale list of the Division.	Price realised as per sale list.	Remarks.
					Rs.	
1922-23 .	Compartment 16	Regeneration felling . .	286	...	...	Prescribed for 1920-21, also worked in 1921-22.
	" 3 . .	" " . .	1,929	2,538	10,500	Prescribed for 1919-20.
		Unregulated . .	953	...	...	
	" 1, 2, 4-15, 17, 73, 74	*Insect attack* (*1922*) . .	*974*	**4,411*	*4,000*	*Not given in the list of produce of the division.
	" 18-31, 41, 42 . .	" " " . .	*684*			
	" 43-58, 66, 67, 76 .	" " " . .	*1,546*			
	" 32-40, 59-65, 68-72, 75.	" " " . .	*921*			
1923-24 .	Compartment 56 . .	Regeneration felling . .	...	2,088	5,400	Figures from F. Z.'s enumeration list.
	" 57 . .	" " . .	...	1,664	4,800	
	" 58 . .	" " . .	...	2,484	6,500	
	All compartments except 1, 2, 8, 30, 72, 75.	*Insect attack* (*1923*) . .	...	*2,625*	*3,389*	
1924-25 .	Compartments 1-76 .	*Insect attack* (*1924*) . .	...	*1,438*	*3,797*	

APPENDIX II.

Table showing the total number of Hoplocerambyx spinicornis *attacked sal trees (all classes) marked in Thano Forests, Dehra Dun Division, W. Circle, United Provinces, during the years 1916-1923.*

Compartment No.	1916.	1917.	1918.	1920.	1921.	Compartment No.	1922.	1923.
1	...	10	161	10	13	1	13	...
2	...	100	...	6	1	2	16	...
3	53	68	440	6	25	3	7	5
4	21	38	447	19	66	4	93	90
5	14	31	354	37	66	5	165	45
6	12	87	137	8	16	6	48	72
7	47	76	399	25	73	7	73	84
8	...	72	...	3	11	8	7	...
9	43	61	139	21	27	9	30	4
10	30	114	156	50	33	10	42	67
11	13	266	1,094	82	65	11	89	58
12	30	119	345	65	58	12	58	39
13	48	148	116	9	36	13	64	56
14	51	28	32	14	14	14	52	35
15	18	14	58	20	4	15	45	8
16	44	11	77	6	2	16	17	16
17	11	34	92	4	4	17	10	9
18	43	60	207	12	42	18	28	8
19	41	67	220	17	13	19	38	3
20	55	80	259	23	63	20	51	17
21	11	131	272	38	16	21	47	29
22	33	145	92	24	14	22	72	49
23	34	234	63	20	12	23	45	51
24	105	54	100	46	24	24	105	108
25	340	185	110	88	88	25	44	26

APPENDIX II.

Table showing the total number of Hoplocerambyx spinicornis—*contd.*

Compartment No.	1916.	1917.	1918.	1920.	1921.	Compartment No	1922.	1923.
26	147	132	95	20	18	26	50	30
27	306	208	352	18	33	27	69	32
28	92	108	205	7	21	28	30	21
29	23	128	626	47	12	29	71	48
30	9	68	315	5	3	30	21	...
31	18	33	189	5	9	31	16	8
32	48	58	466	24	47	32	42	4
33	3	45	230	19	9	33	42	7
34	28	*32*	*60*	40	54	34	24	26
35	109	*41*	*71*	18	31	35	21	10
36	29	*34*	98	33	38	36	45	40
37	27	*31*	221	42	*21*	37	51	16
38	19	*23*	189	26	*16*	38	39	17
39	261	423	950	238	266	39	127	22
40	83	145	674	96	85	40	61	21
41	35	53	75	3	14	41	18	1
42	38	157	294	9	40	42	57	19
43	61	223	487	8	29	43	29	15
44	92	517	...	35	146	44	67	58
45	102	233	427	102	83	45	134	42
46	361	981	598	159	157	46	52	121
47	365	1,460	824	112	109	47	129	108
48	*240*	325	1,675	63	147	48	55	34
49	*205*	220	974	126	65	49	46	69
50	*124*	110	764	108	169	50	42	26
51	*190*	347	1,083	111	107	51	33	35

APPENDIX II.

Table showing the total number of Hoplocerambyx spinicornis—concld.

Compart-ment No.	1916.	1917.	1918.	1920.	1921.	Compart-ment No.	1922.	1923.
52	*200*	281	1,494	237	162	52	71	81
53	214	180	578	182	127	53	57	59
54	304	368	1,117	166	517	54	209	131
55		390	377	115	341	55	146	83
56		*140*	488	101	271	56	213	19
57		*336*	1,166	178	271	57	93	26
58	974	*347*	1,200	115	228	58	172	19
59		*103*	358	39	23	59	36	11
60		*37*	138	88	16	60	9	9
61		*57*	204	18	8	61	28	11
62		*47*	107	11	29	62	31	9
63		*226*	513	35	171	63	44	46
64	with 69-72	*75*	171	81	101	64	85	39
65		*258*	588	131	165	65	101	35
66	*91*	109	476	105	209	66	82	64
67	*28*	49	143	11	69	67	16	9
68	86	92	698	85	303	68	28	27
69		49	288	40		69	87	66
70	with 62-65 773	*16*	69	19	849	70		
71		*9*	38	21		71	81	86
72		*3*	11			72		
						73	139	39
						74	80	45
						75	...	...
						76	24	67
GRAND TOTAL.	6,772	11,440	27,480	3,855	5,825	...	4,411	2,625

NOTE.—The figures in italics have been obtained by graphical interpolation.

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PREFACE.

Mr. Raitt has for many years been working to find out an efficient method of dealing with bamboo for paper making, and this record briefly summarises the stage at which his investigations have arrived. There were many difficulties to be overcome, the most important of which were (i) to evolve a method of pulping bamboos so that the percentage of bleach required was reduced within economic limits, (ii) the reduction in quantity of caustic soda required to reduce the raw material to pulp and (iii) the preparation of the raw material to a fit state for digestion.

Up to 1923, Mr. Raitt had at his disposal, first in his private laboratory, later at the Allahabad Exposition of 1910, and finally at the Forest Research Institute, only laboratory plant, but by 1919 his experiments had reached a stage when sufficient evidence was available to show that the process he had evolved, which he terms "Fractional Digestion", promised to solve the problems above enumerated. Such data, obtained in the laboratory, was obviously insufficient to satisfy papermakers and encourage them to adopt the process on a commercial scale, at the same time no firm of papermakers, could be expected to afford the time or money necessary to verify his laboratory results.

In 1919-1920, far-reaching schemes were being considered to extend the laboratories and workshops of the Economic Branch of the Forest Research Institute, and so struck were the authorities with the work Mr. Raitt had carried out on the bamboo pulp investigation, during the years he had worked for this Institute, and its probable eventual effect on bamboo exploitation, that it was decided to give him an opportunity to prove his laboratory results on a large-sized experimental plant in which commercial conditions would prevail, the total cost of which amounted to £12,500, when erected at Dehra Dun.

Mr. Raitt has now had the plant which he describes in this Record working for about a year, and has tested in it several species of bamboo, and also carried out extensive tests with *sabai* grass (*Ischæmum angustifolium*). The results obtained not only confirm his laboratory

work but actually give better results than were anticipated. I have personally carefully watched the various tests carried out and the results obtained, which not only mean a revolution in the methods of dealing with grasses of the *sabai* type, but at once bring the utilisation of bamboo for paper pulp on to an absolutely sound foundation. The above assertions are corroborated by the fact that the large paper mills of India are now adapting their plants to the ' Fractional Digestion ' system.

It gives me the greatest pleasure to be able to state these facts, as I have had the opportunity of watching Mr. Raitt gradually evolve and improve his process and have been fortunate enough to have been associated with him in this bamboo enquiry for many years.

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Forest Economist, Forest Research Institute,
Dehra Dun.

Plate I.

Photo by Har Swarup.

[This publication is printed on bamboo paper made at the Paper Pulp Plant of the Forest Research Institute. The bamboo was digested fractionally with 15·5 per cent. of caustic soda and bleached with 5 per cent. standard bleaching powder on raw bamboo. Bleached yield 39 per cent.]

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Summary of Investigations on Bamboos and Grasses for Paper Pulp.

BY

W. RAITT, F.C.S., M.I. CHEM. E.

The Paper Pulp Plant at the Forest Research Institute.

1. This plant has now been at work long enough to permit some account of its activities to be published. Its purpose is to experiment, by factory methods, with plant materials of Indian forests and waste lands for which no use has hitherto been found, but which may have possibilities as sources of papermaking fibre stock. Government is, by means of this plant, undertaking risks which the pioneer industrialist but too often comes to grief upon, and the results, whether positive or negative, are of equal value to him. For this purpose it is not necessary to conduct experiments upon a full commercial scale. So long as the plant is large enough to compel commercial methods as distinct from laboratory methods, which although a necessary preliminary to large-scale action are not always convincing to the commercial mind, the results will be exactly comparable to efforts on a scale ten times greater.

2. The plant is on a scale of what a papermaker would describe as a " 35 inch Fourdrinier " and consists essentially of a pair of digesters fitted for either *Fractional* or *Overhead* digestion with a Fourdrinier pulp and papermaking machine carrying a wire 35″ wide, and the auxiliary plant required for beating, washing and preparing raw material for digestion. It was constructed by Messrs. James Bertram

and Son, Ltd., Edinburgh, and erected by the Institute staff and is capable of dealing with 20 tons of raw material per week. A boiler, common to all the steam using plants of the Institute, supplies driving and digestion steam.

3. An important feature of the plant is the adoption of what has come to be known as " fractional digestion " and, to understand it, a brief account of the laboratory investigation and discoveries which led up to it is necessary. The laboratory work had already established the fact that the principal field of the Institute's efforts must lie in certain groups of *Gramineæ*, notably bamboos, Savannah grasses and grasses producing annual culms, of which *sabai* (*Ischæmum angustifolium*) is a type. It is true that woods, spruce and fir, similar to those so largely used for papermaking in Europe and North America, exist in immense quantities in the Himalayas but generally under conditions which raise transport costs to a prohibitive figure, and their increasing value for constructional and railway purposes places them beyond the papermaker's reach. Such *Gramineæ* contain a very large proportion, fully a third of the whole, of starch and pectin constituents and in this fact lies the peculiar value of the fractional method for dealing with plants of this description. Woods contain only an insignificant amount of these substances. It was during an intensive exploration, extending over some years, of the problem of bleaching bamboo pulp, which had hitherto prevented the employment of this material, that the facts and principles now to be referred to were discovered. And as an introduction to what follows it will be useful to quote from Messrs. Cross and Bevan's " Papermaking ", 5th edition, pages 104-5, as under:—

" A useful method of investigation of plant materials for papermaking, specially applied to the order *Gramineæ* has been developed by W. Raitt in his reports on Bamboo and certain Indian Savannah Grasses."

" According to this system, the organic constituents of the plants are divided into four groups ":—

" *Group I.*—Soluble in boiling water. This includes starch and its transformation products, sugars, soluble gums, tannins, colouring matter, etc.

" *Group II.*—Removed by 1 per cent. NaOH solution at 100°C. This includes resins, fats, waxes, gums insoluble in water and, principally, pectose.

" *Group III.*—Lignin. This is separated, after extraction of substances of Group II, by chlorination and extraction with sodium sulphite. It is also converted into soluble derivatives by digestion with NaOH of a concentration of 4 per cent. or more, at temperatures above 130°C. In

this treatment however, more or less of the Beta-Cellulose is hydrolysed and dissolved so that it is not suitable as an analytical method.

" *Group IV.* Alpha-Cellulose (more resistant) and Beta-Cellulose (less resistant) determined as a residue from the chlorination treatment."

" Raitt has determined the amount of caustic soda consumed or neutralised by each of the groups separately under ordinary conditions of digestion. Thus it is possible to calculate from the analytical results the theoretical quantity of caustic soda consumed in the digestion of the plant material ".

Analyses.

4. Typical analyses of several species of Indian *Gramineæ* according to the progressive solubilities of their constituents in accordance with the above method are as follows, (the figures are all related to an average air-dry condition of ten per cent. moisture):

—	Moisture.	Group I Starches.	Group II Pectins.	Group III Lignins.	Group IV Cellulose or Pulp.
Sabai—					
(*Ischæmum angustifolium*) . .	10	11·76	29·88	4·9[illegible]	43·40
Savannah grass—					
(*Saccharum arundinaceum*) . .	10	0·44	24·73	8·24	47·59
Bamboo—					
(*Bambusa polymorpha*) . . .	10	8·05	18·54	14·17	40·24

This analytical method by solubilities is an exact reflex of what occurs in the papermaker's digester not only as regards the individual solutions but also in their progression. It permits the characteristics of each group to be examined and the soda consumption of each to be ascertained. Having got the solubles separated, it occurred to us that they might not all be equally responsible for the extreme resistance of bamboo to bleaching, for another line of enquiry, suggested by work previously done by Cross and Bevan, revealed the fact that it was not the cellulose itself which was unbleachable but something which it re-absorbed after digestion had reached the stage where it breaks down into pulp. This idea was reinforced by the common knowledge that pure cellulose absorbs colour with an extraordinary facility.

5. Our examination of group characteristics revealed the following:—

Group Characteristics.

Group I, although soluble in boiling water, will combine with soda to a small extent if it can get it, as it can in the papermaker's digester. Starch combines to produce a clear colourless solution but its secondary and transformation products, which constitute three-fourths of the group, yield a dark brown, nearly black, solution of great staining power which cellulose absorbs and which has afterwards to be destroyed by bleaching.

Group II, composed chiefly of pectins, combines to produce a dark brown solution which is not only staining but is gelatinous. On cellulose it produces a brown stain which, owing to this gelatinous and viscous quality, clings to the pulp and will not wash out and can only be destroyed by excessive bleaching.

Group III, lignins, yields a clear, limpid, amber colour solution, non-staining, which washes out of the pulp with extreme facility.

It now appeared to be established that the degraded products formed by the combination of Groups I and II with soda were the cause of the bleaching trouble and the course clearly indicated is to get rid of these before the material breaks down into a condition in which it is capable of absorbing them, *i.e.*, into pulp, and such a process was facilitated by these facts:—

(*a*) The material does not break down into pulp until the lignin is removed.

(*b*) Groups I and II are easily soluble at comparatively low temperature and in a weak (1 to 2 per cent.) soda solution.

(*c*) Lignin is fully soluble only at high temperatures (above 130°C), and in strong soda solution (4 to 5 per cent.).

Therefore, get rid of the unbleachables before attacking the lignin. *Hence fractional digestion.*

6. The old method deals with all three groups in one all-in or '*Overhead*' operation and it must do so necessarily by treatment drastic enough in soda and temperature to resolve the most resistant group, lignin, which is unnecessarily severe for Groups I and II. When digestion is complete we have a mass of liberated pulp steeped in the degradation products of the two latter groups and the result is a badly stained pulp which requires severe bleaching to de-colour it, so severe that considerable fibre losses occur through a bleaching oxidation of the fibre. Groups I and II naturally go into solution first while the temperature is rising to the point of lignin attack, and when that point is reached these groups have combined with two-thirds of the soda present, leaving its active density too low for an

efficient attack on lignin unless the soda contents have been bolstered up by a large excess of soda (often as much as 6 per cent. on the grass weight). This ensures an efficient density at this point, and is what is usually done. Such an excess is wholly a contribution to density, *not to consumption*, and it will be found in the discharged waste liquor as unused and unaltered Caustic Soda. It will be observed that groups I and II, dissolving as they do in the earlier stage of digestion, do so in a solution of strong density while at the later stage a weakened solution is presented to the strongly resistant component, lignin: a progression which is obviously wrong and which the *fractional* method reverses with great benefit to the effective clear-out of all three groups and a substantial saving of soda. It is no longer necessary to bolster up density by soda which remains unused.

Liquor Density.

7. It had now become evident that the successful application of the *fractional* method depended greatly on the reaction of lignin to liquor density and, as a reflex from that, the effect of temperature upon hydrolysation of cellulose. Lignin was found not to be uniform in resistance but to vary considerably with species. Nature's rule in the case of grasses appears to be:—*the shorter the period available for lignification during growth the less the quantity of lignin but the greater its resistance.* Thus *sabai*, with a lignification period of about two months, contains about 5 per cent. of strongly resistant lignin while bamboo with a period of fifteen months exhibits three times that amount of a less resistant character. Caustic soda solutions possess the peculiar quality in many operations of having an effective density at which reaction will be quick and effective while a slightly lower density will be slow and inefficient. Investigation along this line showed that the effective density for the lignin of *sabai* is 5 per cent. At 6 it is not appreciably better while at 4 or even 4½ it is appreciably less efficient. In the case of bamboo 4 per cent. is the figure. With *fractional* digestion the shrinkage in volume of the raw material during the Groups I and II stage makes it quite easy to secure liquors containing the necessary quantity of soda in solutions of these densities and their use makes it possible to lower the temperature at which the lignin reaction is carried out and thus influence hydrolysation of cellulose beneficially.

Cellulose hydrolysation.

Temperature was already known to be the factor having the greatest effect on fibre loss. To put it graphically but crudely and not quite accurately, a ten per cent. increase of temperature, say, from 150°C. to 165°C. results in a three times greater loss than a similar addition to either the soda or the time, so it became necessary to investigate the influence of temperature on the hydrolysation of cellulose. As found in grasses it is of two types, always associated, Alpha-cellulose, which is resistant to any temperatures likely to be used, and Beta-cellulose, which may amount to a fifth of the whole, and may be very considerably affected. Some of

it must go, being soluble at the lowest temperature affecting lignin, *viz.*, 130°C., but the bulk of it has a resistance point or critical temperature at which losses become serious and below which they are not appreciably greater than at 130°C. For *sabai* we have fixed this point at 142°C. and for bamboo at between 150°C. and 153°C. *Fractional* digestion can invariably be done at temperatures below these danger points while the *Overhead* method, as always, demands figures at or above them and with corresponding losses.

8. The new method had now reached a stage at which the following economies and benefits could be predicted:—

(*a*) A soda saving of 4 to 6 per cent. on grass, possibly more on bamboo.

(*b*) The production of an unstained and easily bleached pulp.

(*c*) Lower temperature of digestion with larger pulp yield through reduced hydrolysation of cellulose.

(*d*) A reduction of volume and an increase in density of the waste liquor sent to the soda recovery plant thus reducing recovery costs. This is owing to the facility with which lignin-soda liquor separates from pulp and the consequent reduction in volume of wash water required, and also to the fact that the system makes a clean cut between the staining and non-staining liquors permitting the latter to be all used up in digestion operations.

(*e*) An economy of steam from the lower temperature and shortened period of digestion.

Anticipating what follows it may be mentioned here that all these expectations have been fully realised.

Experimental Development.

9. It is unnecessary to detail the long series of experiments required to embody the above related facts and discoveries in a plant capable of working such a process on a commercial scale, but two interesting developments which considerably facilitate the whole process may be mentioned. It was found unnecessary to deal with Groups I and II separately. Both come out together and satisfactorily in weak soda at low temperature. There is a slight waste of soda in the Group I resolution which is more than compensated for by saving steam and time required to deal separately with Group I by water solution. It was further discovered, that when these groups are dealt with by a strong solution at high temperature, as is the case under the *Overhead* method, a secondary combination with soda takes place which uses up a further 2 per cent. to 3 per cent. This is most noticeable with bamboo where the initial temperature under *Overhead* conditions is 162°C. Under *fractional* conditions this is prevented. The other development was contained in the discovery that lignin, like some other colloids, when

in an alkaline solution containing an excess of free alkali, is a better solvent of another colloid than a pure solution of the solvent, consequently, instead of using a pure weak solution for Groups I and II, the lignin-soda solution from a previous digestion, provided it held a sufficient excess of free soda, could be brought back to effect the resolution of Groups I and II. As it is a non-staining solution it can be so used. All that is necessary is to ensure that the fresh strong solution applied to group III contains enough soda for all three groups. The importance of this lies in two directions:—

(*a*) As it is not necessary to use a pure weak solution for groups I and II, the volume of waste liquor sent to the recovery plant is not increased as was at one time anticipated, but is instead reduced; one volume of liquor only, *viz.*, that used for groups I and II after use on group III and containing all the products of the three groups, goes to recovery [see para. 8 (*d*)].

(*b*) The pure soda solution applied to group III now contains enough soda to resolve the three groups so there is no difficulty in securing the high density required for rapid and effective action on lignin, and, since the material at this stage is surrounded by and steeped in two and a half times as much soda as it can use, the result, so far as it is affected by the soda factor cannot go wrong, and the high density permits both time and temperature to be considerably reduced, thus preventing to a large extent hydrolysation of fibre and avoiding the irregular and inefficient digestion which is so common an experience under *overhead* conditions.

Digester Plant.

10 The plant ultimately evolved consists of several digesters, preferably not less than three, working in progressive series and so connected up to each other by piping, valves and screens as to permit the following operations to be performed (we shall denominate the resolution of Groups I and II *pre-digestion*, and of Group III *lignin digestion*, the liquor in which the latter has been conducted *lignin-soda* liquor, the pulp-washes after the latter operation *1st and 2nd washes*, while *spent liquor* will be the liquor sent to recovery after the pre-digestion operation is complete):—

(*a*) blowing lignin-soda liquor and the 1st wash from any digester to any other, or to a storage tank and subsequently to digester;

(*b*) taking steam at a pressure suitable for pre-digestion from the top of any digester in which the lignin digestion is being carried on, to the bottom of any digester in which the pre-digestion stage is in progress;

(c) discharging spent liquor from a point in the side of digester which coincides with the level to which the material shrinks during pre-digestion, thus preventing scum and the light dirt it carries being filtered out by the pulp as is the case in *overhead* treatment. In operation, this valve is opened first and after the supernatant liquor and scum is blown-off the valve at bottom is opened; and

(d) utilising blown-off steam for heating, in overhead tanks, fresh caustic soda liquor and 2nd wash, thus to a large extent preventing steam condensation, with consequent lowering of densities, occurring within digesters.

Where three digesters are more than the mill requires, two or even one may be used but with some loss of time in waiting for re-charging with raw material. In these cases the lignin-soda liquor and 1st wash will be blown to an overhead tank. Three digesters synchronise their operations perfectly, one engaged on pre-digestion, the second on lignin digestion, while the third is re-charging.

11. Results on *sabai* and bamboo obtained in our plant are as under.—

Sabai results.

Sabai by *overhead* treatment required 15 per cent. soda on grass weight, 4 hours steaming at 145°C. (45 lbs.) and 6 per cent. of standard bleaching powder on grass weight. The spent liquor amounted to 1,400 gallons per ton of grass of a density of 5½°Tw.

By *Fractional* the figures were 11·5 per cent. soda, 3½ hours steaming at an average of 136°C. (32 lbs), 1·75 per cent. of bleach and the spent liquor amounted to 900 gallons of 11°Tw. density, while the bleached yield was 2 per cent. more. The economies are therefore:—

	Rs.	A.	P.
78 lbs. soda at Rs 5 per cwt. .	3	8	0
95 „ bleach at Rs. 11-8-0 per cwt.	9	12	0
45 „ more pulp at Rs. 12 per cwt.	4	12	0
Total .	18	0	0

per ton of grass or Rs 1,80,000 on a consumption of 10,000 tons per annum. The above values are at present Indian costs, but the soda figure is for imported soda required to replace losses, and lime *only*, recovery costs being neglected. It is evident from the spent liquor figures that the economy in this direction would be considerable. Steam saving is likewise neglected but it may be mentioned that *overhead* treatment with the *fractional* consumption of steam will not produce a properly digested pulp. Pulp cost is for raw material and chemicals only; coal, labour and fixed charges being neglected. The economy

in soda and bleach cost equals 46 per cent. The process is in use in two of the largest *sabai* mills in Bengal but with the old type of digester, which prevents full colour effect being obtained; nevertheless the total bleach consumption of the mills is less and appearances indicate that on grass it is considerably less. As they bleach a large amount of other materials accurate figures of grass bleaching are not available. On soda the economy is 4 per cent. or one-fourth of their previous consumption.

Bamboo results.

Bamboo by *overhead* treatment requires 21 per cent. soda, 5½ hours steaming at 162°C. (80 lbs.), and 10 per cent. bleach. Spent liquor was 1,600 gallons at 6°Tw. The *fractional* figures were soda 15 per cent., steam 5½ hours at an average of 140°C. (38 lbs.), bleach 5 per cent., spent liquor was 1,000 gallons at 10½°Tw. and pulp was 8 per cent. more. Economy is therefore:—

	Rs.	A.	P.
134 lbs. soda, at Rs. 5 per cwt.	6	0	0
112 „ bleach at Rs. 11-8-0 per cwt.	11	8	0
67 „ more pulp at Rs. 8 per cwt.	4	13	0
Total	22	5	0

per ton of bamboo or Rs. 2,23,125 on 10,000 tons per annum. This amounts to 15 per cent. on present manufacturing charges for materials and chemicals only. If the savings in recovery, coal, labour and fixed charges up to the bleached pulp stage are taken into account the total reduction in cost will be well over 20 per cent. Soda and bleach economy is 38 per cent.

Practical hints.

12. The working of *sabai* pulp through the mill presents no difficulties which have not been overcome during the many years it has been used in Indian mills. Bamboo, however, introduces some new problems which the constructors of new mills would do well to note and so avoid errors in details of their plants. The sap canals, which are numerous and run for long distances through the whole length of the culm, are, in the dry state, filled up with capillary air which is extremely difficult to expel. Crushing, by splitting the canals, gets rid of much of it, which is one of the reasons why we advocate crushing in preference to chipping but even so it carries with it into the digester a considerable mass of capillary air which, in the early stages of the groups I and II treatment, rises up as an enormous volume of froth. It is necessary to get rid of this and, in blowing it off, it entrains and carries out with it a considerable amount of the liquor. We have seen as much as a fourth of the whole charge thus carried away. We are dealing with it by boiling very gently for some time with the digester cover off until the frothing stops but this would not be practicable in a large plant. The proper

cure we think would be a froth-separator placed at a level slightly above the top of digester, the blow-off would be sent through it. When the air has been all expelled the steam outlet from the separator would be closed, and the trapped liquor allowed to flow back by gravity to the digester through a pipe connection at the botton of the separator. One separator could take care of three digesters.

13. Crushing presents no difficulties. It is not necessary to crush the bamboo to a fibrous condition which would greatly increase the bulk and reduce digester capacity. All that is required is to pulverise thoroughly the nodes and split the sap canals. As the nodes are slightly greater in diameter than the internodes, the crushing rolls are set to pulverise the former which setting likewise gives the desired splitting effect on the internodes. After cutting to 1 to 2-inch lengths the crushed and cut material occupies 160 c.ft. per ton from which figure digester measurements can be calculated. After the groups I and II treatment this figure comes down to 126 c.ft. and after lignin digestion to 105 c.ft.

Crushing.

14. Crushing is considerably assisted by a previous soak in water which also removes adhering sand and mud. Except for this, bamboo is a remarkably clean material and, of itself, and provided the nodes are pulverised, carries nothing into the digester which will produce specks and dirt in the pulp, and as mud, etc., is only on the exterior it is easily removed. As an effective means of dealing with this we suggest a water flume alongside the bamboo store sheds through which a gentle current, produced by a slow motion impeller pump pushing the water from one end of the flume to the other, carries the culms on to a traveller where they meet a high pressure spray and thence into the crushers.

Washing Bamboo.

15. We may here allude to one of the reasons for our preference for water transport of bamboos, which our recent experience has confirmed. It is not only a question of cost, which is of course largely in its favour as against land transport, but security of storage is effected. Bamboo which has been three to six weeks rafting down a river loses, by water soakage, a considerable amount of its starchy constituents *upon which boring beetles feed* and which encourage mildew during the rains, and we think it advisable to complete the process by sinking rafts in the stream for a week after their arrival at a mill. This is, in fact, the process of seasoning (as it is called), really merely a removal of the attraction to destructive insects and mildew, in this country for bamboos intended for constructional work. Bamboo thus treated will store perfectly well for two years. We have some here which was transported by land, which in nine months has been reduced to a mass of dust. Such partial extraction of group I has of course a beneficial effect on digestion.

Water Seasoning.

16. Bamboo pulp proves to be extraordinarily " free ", *i.e.*, parts with its water with extreme facility, more so than any other pulp we know. The effect of this is that it parts with most of its water directly it reaches the wire of the drying machine and there is no chance given it to felt and consolidate, with the result that when it reaches the first press it sticks to the top roll like glue. no matter how the suction box and couch treatment is varied, and can only be detached in flakes. We have got over this by slackening back the second press felt and lapping it round the top first press roll so that the sheet runs between two felts through the first press, but we lose some of the water extraction effect which we have to counterbalance by greater pressure at the 2nd press which gives no trouble, the consolidation which the sheet gets at the first press helping it through the second. Our method of getting over the trouble is effective but not ideal as it is somewhat severe on the felts and we commend the question to the attention of pulp engineers for solution, whether by double felting, a polished granite top roll (ours is brass) or some other device. There is, anyhow, no need for a third press. Two pressings bring out all the water that can be extracted by squeezing. Beaten pulp for papermaking gives no trouble. It can be beaten so as to carry its water well over the wire and ' felt ' perfectly.

Bamboo " freeness "

PREFACE.

The experiments carried out by the Forest Research Institute, Dehra Dun, were started on a laboratory scale in 1908, and were gradually extended and enlarged into field experiments entailing service tests on a large number of treated sleepers of different species. The laboratory tests referred to above are recorded in Indian Forest Records, Vol. III, Part II of 1912, while in Chapter IV of that work the lines on which future investigation will be carried out is stated in full. The results of the service tests are recorded in Indian Forest Records, Vol. VI, Part IV of 1918, and Vol. IX, Part I, and in Forest Bulletin No. 59 of 1924. The majority of the sleepers laid down for the above tests were treated in open tanks, and only a few Assam species were treated under pressure. The above durability tests are now nearing completion, as many of the sleepers have been in the line over 12 years.

The results of the above tests have been so satisfactory that, on the enlargement of the laboratories and workshops of the Economic Branch of the Forest Research Institute in 1921-23, it was decided to create a separate section of Wood Preservation, which entailed recruiting a specialist in the subject, giving him the necessary staff and putting in a complete experimental up-to-date treating plant. As soon as the staff and plant became available, and in conjunction with the Sections of Wood Technology, Timber Testing, and Timber Seasoning, a joint scheme of investigation was prepared, known as Project IV, Sleeper Wood Investigation. This Project was, after drafting, submitted to the Railway Board for scrutiny and remarks, and after the necessary alterations and additions had been made to meet Railway requirements, it was accorded the sanction of the Government of India.

The first results of this investigation dealing with the treatment of seven Assam species are now complete, the work and report having been carried out by Mr. J. H. Warr, Officer-in-Charge, Section of Wood Preservation, who was helped, in the treatment of the sleepers, by his Assistant, Mr. S. Kamesam.

The sleepers for these experiments, numbering 1400, were supplied by the Assam Forest Department, and are now to be returned to the Assam-Bengal Railway Co., and laid in their line for durability tests.

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NOTES ON THE ANTISEPTIC TREATMENT OF ASSAM TIMBERS FOR RAILWAY SLEEPERS.

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CHAPTER I.

NOTE I.—Report on the Experimental Treatment with Antiseptic Oils of *Cynometra polyandra* (*ping*).

Two hundred metre gauge sleepers were sent from Assam, for the purpose of these experiments, in January 1924. Of the two hundred, 20 sleepers in ten matched pairs were selected by the Timber Testing Section for the purpose of strength tests; ten sleepers being tested untreated and the ten mates tested after treatment. It was decided to treat these ten last with pure creosote only, and to adopt this oil as the antiseptic for treating the Timber Testing specimens of future species.

Of the remaining 180, 6 were rejected and the rest marked as laid down in Project IV, " Mechanical Strength, Seasoning Properties. Treatment of and Key to certain Indian Sleeper woods."

In the case of *Cynometra polyandra* this mark was $\frac{\text{C. P.}}{\text{47—1 upwards}}$.

The timbers were then stacked in three piles in open crib, in a large well-ventilated godown. The moisture content of 7 sleepers in each

pile was determined by taking borings and at the same time the sleepers were weighed. In this way the dry weight of each of the observation sleepers was determined and its moisture content at various times determined by re-weighing.

The average moisture content of the three piles was 39·8 per cent 39·6 per cent, 40·5 per cent respectively on March 3rd, 1924, whereas on January 10th, shortly after marking, the average moisture content of all the sleepers was 45 per cent.

On May 20th the average moisture content of the three piles was 27·3 per cent, when it was decided to commence treatment.

The weather during January, February, March and April was normal for Dehra Dun; that is to say the atmosphere was gradually and steadily becoming less humid with rising temperature. The month of May was abnormal with lower temperature and greater humidity than usual but with drier atmosphere than in the preceding months. The seasoning was therefore slow during January, February and March but became more rapid during April and May.

It should be noted that whereas the average moisture content of the piles gives an indication of the rapidity with which the sleepers are seasoning, it gives no information as to the dryness of the individual sleepers which, as will be seen later, vary considerably in this respect.

The sleepers on arrival had developed, in some cases, considerable seasoning cracks, but, without taking actual measurements, no deterioration could be observed as the sleepers seasoned out.

In view of the fact that the climate of Assam is much more humid than that of Dehra Dun, it is thought that an average moisture content of between 25 per cent and 30 per cent is all that can be expected of sleepers seasoned under natural conditions in the former province and while individual sleepers seasoned at Dehra Dun shew wide variations in moisture content, it should be noted that they were seasoned quickly, due to the drier climate, whereas in actual practice, no doubt, longer time will be taken over this very important part of timber preservation, which will give the slower seasoning sleepers a chance to approach more nearly to the average.

It is impossible to say more about the seasoning of these sleepers, as what will happen under Assam conditions cannot be foretold from what happens at Dehra Dun, but it is anticipated that the seasoning will be slower and more even and therefore more suitable for wood preservation provided the moisture content can be got down to between 25 and 30 per cent.

The sleepers were adzed and bored before treatment.

ANTISEPTICS USED.

As one object of Project IV is to determine the relative economic cost of treatment with various antiseptics, batches of sleepers were treated with the following oils :—

1. Pure Coal Tar Creosote (The term Pure Coal Tar Creosote here means Coal Tar Creosote without any adulterant).
2. Mixture of Coal Tar Creosote and Earth Oil in varying proportions, *viz.*, 50-50, 33-67, 25-75.

To explain the reason for this, it must be assumed that the cost of treatment is to be regarded as an item of capital expenditure, from which the amortisation cost per year can be calculated for the life of the sleeper. It does not follow that, because there is a high initial saving by treating with a mixture of creosote and earth oil, that this is the most economical procedure in the long run, because, possibly, the sleeper will be much better preserved by creosote alone. When, however, the length of life of the sleeper is determined from actual experiments in the line, by reference to the amortisation curves, given with this report, the most economical procedure can quickly be determined for any initial cost of treatment.

Moreover, it is undoubtedly a fact, that the greatest economy will be obtained when the sleeper fails from mechanical and chemical break down simultaneously, and the best treatment, therefore, is the one which brings this about.

It may, and probably will, vary for different species and for different localities owing to changed local conditions both as regards climatic factors and cost of operation.

PROCESSES EMPLOYED.

When experimenting with an unknown timber, the choice of process is generally evolved during the experiments. For India, it was decided that two processes only were admissible, namely, Lowry and Full Cell.

It was also decided that the Lowry Process should only be used in cases where a regular and thorough penetration was obtained, as when the timber is saturated, surplus oil is wasted, and the saturated condition gives an empty cell process a much greater chance of success.

With *Cynometra polyandra*, owing to its somewhat erratic behaviour, it was thought advisable to use the Full Cell Process almost exclusively although the Lowry Process was also used for purposes of comparison.

Previous Records.

Although no authentic records are available as to the *untreated* life of a *Cynometra polyandra* sleeper, it is not looked upon as a durable wood, and a longer average life than five years is not anticipated under service conditions.

In 1915 the Forest Economist, Mr. R. S. Pearson, instituted a series of experiments by treating various species of Assam timbers at Jaipur in open tanks. Eight sleepers of *Cynometra polyandra* were treated and laid in the Assam-Bengal Railway for service tests. It was observed that the absorption of the antiseptic (equal mixtures of Green Oil and Crude Earth Oil) was erratic, varying from 3·5 lbs. to 18 lbs. per sleeper, the average being 6·5 lbs. per cubic ft., but nevertheless the service records shew that up to December 1923 no sleepers had been rejected, while seven were in first class condition and one was deteriorating (*See* Forest Bulletin No. 53, p. 23).

A little later, 18 M. G. sleepers of this species were treated under pressure with a mixture of Green Oil and Assam Earth Oil in equal proportions. The wood took up an average of 4·5 lbs. of oil per cubic foot. The service record shews that, of these sleepers, which were laid in the line in January 1916, 16 were good and sound in December 1923, while 2 had been removed.

Thus it is seen that *Cynometra polyandra*, when treated with an antiseptic oil, is not nearly at the end of its useful life after more than eight years' service.

Records of present experiments.

Experiment I. Sleepers $\frac{\text{C. P.}}{47\text{—}1 \text{ to } 22}$.

Average moisture content of sleepers : 26·6 per cent.

Average Specific Gravity of Charge : ·94

Antiseptic : 50-50 Creosote and Earth Oil Mixture.

The average gross absorption of oil under a pressure of 175 lbs per square inch, built up and maintained for one hour, was 7·7 lbs. per cubic foot as determined by measurements on the service tank. This absorption was reduced to an average of 5·95 lbs. per cubic foot by means of a vacuum applied after treatment.

Reference to the data of Experiment I will show that the absorption for individual sleepers was somewhat erratic, varying from 2·3 to 11·3 lbs. per cubic foot. At the same time it may be remarked that, although the average moisture content was 26·6 per cent, individual sleepers varied considerably.

On cutting sleeper number 13 it was found that the oil had completely penetrated the sleeper. This sleeper took up 5·6 lbs of oil per cubic foot, a very close approximation to the average of 6 lbs. per cubic foot.

During the experiment it was noticed that, after the pressure had been maintained for 20 minutes and built up to 175 lbs. per sq. inch. the oil was entering the wood at the rate of 1 lb. per cubic foot in five minutes, just half the rate for the previous five minutes, during which period the pressure had risen from 150 to 175 lbs. per sq. inch.

Experiment II.—Sleepers $\frac{\text{C. P.}}{47\text{—}23 \text{ to } 47}$ except 25.

This charge was treated by the Lowry Process using a 50-50 Mixture of Creosote and Earth Oil as the antiseptic.

The average moisture content of the sleepers was 27·04 per cent although individual sleepers varied from 17 per cent to 57 per cent.

Although the pressure was maintained for one-and-a-half hours no better gross absorption than 6·7 lbs of oil per cubic foot could be obtained. By means of a vacuum the nett amount of oil retained by the charge averaged 5·6 lbs. per cubic foot, and varied in individual cases from 2 lbs. to 8·3 lbs. per cubic foot.

Sleeper No. 30, whose moisture content was 21 per cent, absorbed 8·3 lbs of oil per cubic foot and was found to be evenly impregnated to a depth of ½ inch all round. On cutting sleeper No. 42, whose moisture content was 17 per cent and absorption 6 lbs. per cubic foot, it was found that the sapwood was entirely impregnated and that the heart surface was penetrated evenly to a depth of ½ inch. The wood absorbed, in the first seven minutes after the pressure was started, about 3 lbs. of oil per cubic foot, the pressure meanwhile rising to 100 lbs. per sq. inch. After 30 minutes, in spite of the pressure having been raised to 175 lbs. per sq. inch, the absorption was very slow, the wood having absorbed by now 4·5 lbs per cubic foot. In the next 10 minutes, the pressure still being maintained at 175 lbs. per sq. inch, the wood absorbed 1·75 lbs. per cubic foot and from then onwards till the experiment was completed there was no greater absorption than ·5 lb. per cubic foot. This experiment would seem to indicate, in conjunction with Experiment I, that the wood is impregnated to refusal after about 50 minutes to one hour under a pressure of 175 lbs. per sq. inch.

Experiment III.—Sleepers $\frac{\text{C. P.}}{47\text{—}48 \text{ to } 67}$.

Owing to the fact that the absorption of oil by the wood was somewhat erratic in the previous experiments it was thought best to revert to the Full Cell Process.

A mixture of 37 per cent Creosote and 63 per cent Earth Oil was used as the Antiseptic. The average moisture content of the sleepers was 28·3 per cent and the Specific Gravity ·92. Here again the moisture content of individual sleepers was found to vary from 21 per cent to 50 per cent.

The pressure was maintained for one hour, and gave an average gross absorption of 5·4 lbs per cubic foot for a composite charge with nine sál posts. This was reduced slightly by the final vacuum giving an average nett absorption of 5·57 lbs. per cubic foot for *ping* alone. The variation was from 3 lbs. to 9·6 lbs. per cubic foot.

On cutting sleeper number 67 whose moisture content was 23·6 per cent and whose absorption was 9·6 lbs per cubic foot, it was found that the oil had completely penetrated the sleeper.

Sleeper number 57 whose moisture content was 24·7 per cent retained only 3 lbs. of oil per cubic foot. On cutting the sleeper it was found that the sapwood was completely impregnated but, although flecks of oil appeared throughout the heartwood, the heart surface was not impregnated to any great depth Sleeper number 53 with a moisture content of 33·3 per cent retained a little more than the average, *viz.*, 6·3 lbs. per cubic foot. It was found to be composed of sapwood to the extent of 80 per cent and this was almost completely impregnated. The heart was not penetrated to any depth.

During the experiment it was noticed, that in the first five minutes the wood absorbed about 2·5 lbs. of oil per cubic foot, the pressure having risen to 75 lbs. per sq. inch.

In the next ten minutes, the wood absorbed 1·75 lbs. per cubic foot and the pressure rose to 125 lbs. In the next ten minutes it absorbed a little less than 1 lb. per cubic foot, while the pressure rose to 175 lbs. per sq. inch. During the next 30 minutes, with the pressure still maintained at 175 lbs. per sq. inch, the wood only took up a further ·75 lb. per cubic foot, nothing being absorbed in the last 10 minutes. It is therefore confirmed that the wood can be treated to refusal by the Full Cell Process in one hour.

Experiment IV. Sleepers $\frac{\text{C. P.}}{\text{47—68 to 91}}$.

The Full Cell Process was again employed, and the pressure kept on for 2 hours 15 minutes, in an endeavour to make the wood take more oil than in the previous experiments.

The average moisture content of the charge was 28·5 per cent and the Specific Gravity of the wood ·97.

The moisture percentages were much more uniform than in the previous experiments, owing to the drier atmospheric conditions at the time of treatment. The percentages varied from 16 to 38 per cent.

The same antiseptic was used as in Experiment III. The average gross absorption was 6·2 lbs. of oil per cubic foot, and the nett oil retained 6·1 lbs. per cubic foot. For individual sleepers the amounts varied from 2·3 to 10 lbs. of oil per cubic foot. Several days were allowed to elapse before cutting the sleepers in order to allow the internal stresses set up during treatment to become stable. Sleeper number 72, whose moisture content was 23·6 per cent, took up only 2·3 lbs. of oil per cubic foot. The sapwood was entirely impregnated, but the heartwood only slightly penetrated.

Sleeper number 90, with a moisture content of 36·6 per cent retained 6·3 lbs. of oil per cubic foot. 80 per cent of this sleeper including the sapwood was thoroughly saturated.

Ten minutes after starting the pressure, the wood had absorbed about 2·5 lbs. of oil per cubic foot, the pressure rising to 60 lbs. per sq. inch. In the next ten minutes the wood absorbed ·75 lb. per cubic foot, and the pressure rose to 80 lbs. per sq. inch.

It will be noted, that in this experiment, the pressure was raised much more slowly than in the previous experiments.

In the next twenty minutes, the wood absorbed less than ·5 lb. of oil per cubic foot, the pressure rising to 120 lbs. per sq. inch.

In the next 30 minutes, the pressure was raised to 165 lbs. about 1 lb. of oil per cubic foot being absorbed. During the next hour, with the pressure at 175 lbs. per sq. inch the wood absorbed 1·5 lbs. of oil per cubic foot, in the last twenty minutes of which no absorption took place.

In point of fact, after the pressure of 175 lbs. had been maintained for 30 minutes, no absorption took place. Once more it is apparent, that the wood can be treated to refusal in one hour, during the last half of which the pressure should be kept at 175 lbs. per sq. inch.

Experiment V.—Sleepers $\frac{\text{C. P.}}{\text{47—93 to 111}}$

In this experiment Creosote only was used as the antiseptic.

The moisture content averaged 24·7 per cent but varied in individual cases from 19 per cent to 40 per cent. The weather was getting much warmer and the atmosphere drier.

As before, the Full Cell Process was used and an average of 8·7 lbs. of oil per cubic foot pressed into the timber under a pressure of 175 lbs. per sq. inch for 45 minutes.

The variation in individual cases was from 3·7 lbs. per cubic foot to 13·7 lbs. per cubic foot. Although the average amount of oil absorbed

was higher in this experiment than in previous ones, and obtained with greater ease, it would be dangerous to suggest that it is due to using pure Creosote only. The variation in absorption between individual sleepers was just as much as in previous experiments. The moisture content was also lower.

Sleeper number 97, on being cut, was found to have the sapwood satisfactorily impregnated but the heartwood shewed no uniformity of penetration. The nett amount of oil absorbed by the sleeper was 7 lbs. per cubic foot, and its moisture content was 40 per cent.

Five minutes after the pressure was put on the oil, the timber had absorbed about 3 lbs. of oil per cubic foot and the pressure had risen to 20 lbs. only. In the next five minutes about 1 lb. per cubic foot was absorbed, the pressure rising to 40 lbs. In the next twenty minutes the pressure rose to 165 lbs. and the amount of oil absorbed was about 3 lbs. per cubic foot.

The pressure was then raised to 175 lbs. and at the close of the experiment the oil was still entering the wood at a slow rate, about 1 lb. per cubic foot in 15 minutes.

It would appear, therefore, that the previous results are again confirmed, and although the average absorption was much higher in this experiment than in the others, the point where the wood refused to take more oil, was reached within the hour. It will be noticed that the pressure was put on very slowly in the initial stages.

Experiment VI.- Sleepers $\frac{\text{C. P.}}{\text{47—112 to 124 and 5 also 1 to 10}}$.

The antiseptic used was Creosote only as in Experiment V ; the average moisture content of the timber being 24·7 per cent.

The variation in individual cases was from 11 per cent to 37 per cent with an extreme case of 90 per cent. This later figure is doubtful.

The pressure was raised to 100 lbs per sq. inch for 20 minutes, followed by a pressure of 175 lbs. for 20 minutes.

The average nett absorption was 7·6 lbs. per cubic foot, varying from 2·6 to 12 lbs. in individual cases.

Sleeper number 112 with moisture content of 26·7 per cent absorbed only 3 lbs. per cubic foot. On cutting the timber it was found that the heartwood had a surface treatment only but the sapwood was penetrated to a depth of 1 inch.

Sleeper number 117 with moisture content of 11·2 per cent absorbed 7·6 lbs. of oil per cubic foot and was completely penetrated.

Owing to the fact that the door of the cylinder leaked when the pressure exceeded 100 lbs. per sq. inch, the cylinder had to be emptied, the door made tight and the experiment restarted. It was therefore not possible to note the rate at which oil entered the wood during the ex-

periment. The indications are, however, that the rate was the same as in previous experiments.

Experiment VII.—Sleepers $\frac{\text{C. P.}}{47\text{—}125 \text{ to } 148}$.

The oil used was a mixture of 30 per cent Creosote and 70 per cent Earth Oil.

The average moisture content of the sleepers was 23·9 per cent varying from 15 per cent to 45 per cent in individual cases.

The pressure was raised to 175 lbs. per sq. inch in 40 minutes, giving an average absorption of 5·4 lbs. per cubic foot which varied from 2·6 lbs. to 8·0 lbs. in different specimens.

Sleeper number 133 absorbed 5·6 lbs. per cubic foot and 70 per cent of the cross section was saturated.

Sleeper 134 absorbed 3·3 lbs. per cubic foot and on cutting, it was seen that the heartwood had received a surface treatment only whereas the sapwood was penetrated to a depth of 2 inches.

Practically the same observations as regards rate of absorption were made as in former experiments.

Experiment VIII.– Sleepers $\frac{\text{C. P.}}{47\text{—}149 \text{ to } 172}$.

The antiseptic used was a mixture of 25 per cent Creosote and 75 per cent Earth Oil.

The average moisture content of the wood was 20·6 per cent with variations from 13 per cent to 35 per cent.

The pressure was raised to 175 lbs. per sq. inch during one hour, and an average nett absorption of 5·1 lbs. of oil per cubic foot obtained. The absorption varied from 2·6 lbs. per cubic foot to 10·3 lbs. per cubic foot in individual cases.

Sleeper number 149, with moisture content of 20·2 per cent, absorbed 3·3 lbs. per cubic foot. The sapwood was completely penetrated while the heartwood was penetrated to depth of ¼ inch.

Sleeper number 163, with moisture content of 19·9 per cent absorbed 5·3 lbs. per cubic foot. The distribution was practically complete in the sapwood but erratic in the heartwood.

Whereas the wood absorbed in the first 5 minutes more than 3 lbs. per cubic foot while the pressure was rising to 100 lbs. per sq. inch it absorbed practically nothing in the last twenty minutes with the pressure at 175 lbs. per sq. inch.

CONCLUSIONS.

From the above experiments, it will be seen that *Cynometra polyandra* is amenable to treatment but that it behaves in a somewhat erratic manner.

It is true that the moisture content of the wood under experiment varied considerably, but, from the figures, nothing definite can be said as to its influence on the absorption. Generally speaking, it is an accepted fact that a moisture content superior to 30 per cent or fibre saturation point, affects the absorption adversely but there are quite a number of exceptions, as shown in the above experiments. Moreover this erratic behaviour does not disappear as the experiments proceed, although the average moisture content gets less and the extreme moisture percentage becomes lower.

It is, therefore, not possible to attribute this variation in absorption to moisture alone, although it probably has something to do with it.

Again, with different mixtures of Creosote and Earth Oil, the average absorption is practically the same, so that the oil is not the cause of it. When Creosote alone was employed, the average absorption was certainly higher than when the mixtures were employed, but it would be unwise to state that Creosote penetrates better than the mixtures, although it may well be the case.

On sectioning the sleepers it was found that with an absorption superior to 5 lbs. per cubic foot the distribution of the oil was satisfactory.

It should be noted here, that a satisfactory distribution of antiseptic does not necessarily imply the complete saturation of the timber, but means that a sufficient depth of penetration is secured to give protection. Higher absorptions than 5 lbs. per cubic foot, in general, gave more satisfactory distributions and in some cases complete penetration.

With absorptions lower than 5 lbs. per cubic foot the sapwood was entirely penetrated but the distribution in the heartwood was erratic, in some cases only a surface treatment being obtained.

The inference, therefore, is that the nature of the wood either on account of its structure or its resin content or some other cause peculiar to the species tends to prevent uniform absorption. It is at present, therefore, advisable to use only the Full Cell Process and impregnate the wood to refusal.

The average absorption of oil should be in the neighbourhood of 7 lbs. per cubic foot and a pressure of 175 lbs. per sq. inch should be maintained for at least 30 minutes, this pressure being developed in the first half hour.

Usually, in impregnating wood to a specification, the required quantity of oil is forced in irrespective of the time taken to inject this quantity, but, as is shown by these experiments, there is not much point in prolonging the pressure period beyond one hour, provided the maximum of 175 lbs. per sq. inch has been reached and has been maintained for 30 minutes.

Unfortunately, the vacuum pump at Dehra Dun is not capable of developing a higher vacuum than 17 inches which, corrected for altitude, will not be greater than 20 inches at sea level. It is therefore possible that slightly better results would be obtained when operating on a commercial scale, *i.e.*, with a higher vacuum of about 24 inches a slightly heavier and more uniform absorption might be obtained.

The specification for treatment would therefore be,—

Initial vacuum 20 to 24 inches developed in 30 minutes and maintained for a further 15 minutes.

Pressure rising to 175 lbs. per sq. inch in 30 minutes and maintained for about 30 minutes or until required absorption is obtained, but not less than 30 minutes.

Gross absorption of oil 7·5 lbs. per cubic foot.

Final vacuum 15 inches for 10 to 20 minutes, to prevent dripping after removal of timber from cylinder.

This will probably remove about ·5 lbs. of oil per cubic foot giving a nett treatment of 7 lbs. per cubic foot.

NOTE II.—Report on Treatment of *Dipterocarpus pilosus* (*hollong*).

One hundred and ninety-three metre gauge sleepers of this species were sent from the Lakhimpore district of Assam for treatment according to Project IV.

They arrived on January 2nd, 1924 and after marking, were stacked in two piles, in a closed well-ventilated godown.

On examination they proved to be very fair specimens but had developed a certain number of cracks either in transit or just after conversion.

20 specimens, in ten matched pairs, were handed to the Timber Testing Section for tests on the treated and untreated sleepers. Ten were tested untreated, the other ten being kept by the Timber Testing Section until required for treatment by the Wood Preservation Section. After treatment they were returned to the Timber Testing Section.

Twelve of the sleepers were rejected as being unfit for use on account of cracking.

The remainder were marked according to a scheme by which the first letters of the botanical name were cut on the broad surface furthest from the sapwood.

Under these letters were cut the serial number of the species and the individual number of the sleeper, *e.g.* $\frac{\text{D. P.}}{4 \quad 1 \text{ to } 161}$.

The average moisture content on arrival was 64·3 per cent., the sleepers thus being quite green. They were adzed and bored before treatment.

These sleepers were seasoned under the same conditions as *Cynometra polyandra* (*ping*) until 27th March when their moisture content was 58 per cent. They were then transferred to the Tiemann seasoning kiln in order to hasten the seasoning process and prepare them for treatment.

They could only be kept in the kiln for ten days in which time the moisture percentage was reduced to 52 per cent. in the centre. The exterior was drier.

It was decided to commence treatment on 28th April although the moisture content average was 43 per cent. Three charges were treated on consecutive days but the treatment was found to be very erratic, and, as this might be attributed to the high moisture content of the sleepers, it was decided to allow the timbers to dry out a little more.

The treatment was recommenced on June 6th, the average moisture content being 39 per cent. The final charge was treated on June 23rd

when the average moisture percentage was 28·5 per cent., shewing how rapidly this timber dries out in a suitably dry climate.

As a summary it may be stated that from the beginning of January till the end of March only 6 per cent. of moisture was lost. Ten days in the kiln reduced the moisture percentage by another 6 per cent., or possibly a little more, as the interior of the sleepers was wet and on allowing them to stand in the godown they evened down to 43 per cent. after about fourteen days.

During the whole of May they lost only about 5 or 6 per cent., the weather being unusually cool; but during June the moisture content was reduced from 39 per cent. to 29 per cent in fourteen days or at a rate of 20 per cent. per month. This caused a slight opening of the wood and may be said to be a more rapid rate for air drying than is safe with such dense timbers.

The kiln seasoning rate was approximately the same but resulted in no damage to the timbers as the humidity of the surrounding atmosphere was under control, although the temperature of drying was higher than the temperature of the atmosphere in the godowns.

LIFE UNTREATED.

Authentic records of the life of this timber untreated are rather meagre. In February 1917 six untreated sleepers of *Dipterocarpus pilosus* were laid in the Eastern Bengal Railway in shingle or brick ballast. At the end of 1922 all sleepers shewed signs of cracking, two having developed very marked longitudinal cracks but none had been rejected.

The timber however is not regarded as durable in exposed positions and a life of more than four years is not to be expected.

PREVIOUS RECORDS.

In 1915, 42 metre gauge sleepers were treated in open tanks with a mixture of Green Oil and Liquid Fuel Oil in the proportion of 9 to 11.

They absorbed 7·4 lbs. per cubic foot and were laid in the Assam Bengal Railway in November of the same year. At the inspection in January 1925, 21 were placed in A class and 18 in B class while only 3 had been rejected.

The report stated that there was a certain amount of splitting at the ends which was the cause of 9 sleepers being placed in B class. The bottoms when inspected were seen to be as good as the day when the sleepers were laid, even after nine years service.

142 sleepers treated under pressure with the same oil absorbed on an average 9·7 lbs. per cubic foot and were laid in the Assam Bengal

Railway line in October 1915. In January 1925, 67 were classed as A, 51 as B, 13 as C and 11 had been rejected. A certain amount of splitting was again noted and there were some signs of dry rot in a few sleepers.

49 specimens similarly treated were laid in the same system in 1916. They absorbed 9·7 lbs. per cubic foot. In January 1925, 34 were in A class, 8 in B class, 1 in C class and 6 had been rejected. The report stated that they presented a very favourable appearance.

Mechanically, therefore, the timber appears to be strong enough to give at least 12 years' life.

PRESENT EXPERIMENTS.

Treatment was commenced on 28th April 1924.

Experiment I.—Sleepers $\frac{\text{D. P}}{4\text{—}1 \text{ to } 20}$ were treated with a mixture of 50 per cent. Earth Oil and 50 per cent. Creosote by the Lowry Process.

The average moisture content was 43·4 per cent but the moisture content varied in individual cases from 14 per cent to 65 per cent.

The average Specific Gravity of the wood at the above moisture content was ·81.

A pressure of 160 lbs. per sq. inch was developed in half an hour until the gross absorption exceeded an average of 8 lbs. per cubic foot.

A vacuum of 16 inches for $\frac{3}{4}$ of an hour was afterwards developed in the cylinder.

An average nett absorption of about 5·4 lbs. per cubic foot was retained by the sleepers. The variation in individual cases was from 2·6 lbs. to 8·6 lbs. per cubic foot, nearly every sleeper retaining a different amount.

Sleeper number 9 with a moisture content of 42 per cent., on being cut at the rail seat, was found to have oil throughout the timber. The ends were completely saturated for a considerable distance along the sleeper and the oil had also penetrated throughout the sleeper in the middle section. This sleeper retained 8·6 lbs. of oil per cubic foot.

During seasoning, the resin in the wood had oozed from the ends so as to cover them. Sleeper number 14, which had no exuded resin on the ends, retained only 2·6 lbs. of oil per cubic foot although its moisture content was 4 per cent. On cutting under the rail seat it was found that the sapwood was entirely saturated and that the heartwood was mottled with oil throughout. The ends were completely saturated for a considerable distance along the sleeper.

Experiment II.—Sleepers $\frac{\text{D. P.}}{4\text{—}21 \text{ to } 40}$.

The same oil as in Experiment I was used and the sleepers were again treated by the Lowry Process.

A pressure of 160 lbs. per sq. inch was developed in 30 minutes, the final vacuum being 16 inches for ¾ of an hour.

The average gross absorption was 7 lbs. per cubic foot.

The average moisture content of the sleepers was 40·5 per cent. with variations from 15 per cent to 111 per cent., this latter figure being doubtful.

The average Specific Gravity of the wood was ·81.

The average nett absorption was 4·9 lbs. per cubic foot with variations from 3·6 to 7 6 lbs. of oil per cubic foot ; rather less erratic than in Experiment I.

Sleeper number 26 with a moisture content of 51 per cent., absorbed only 3·6 lbs. per cubic foot but on being cut open was found to have oil in patches throughout the wood. Sleeper number 39 with a moisture content of 27·1 per cent. retained 7·6 lbs. of oil per cubic foot and on being cut open showed the same penetration.

Experiment III.—Sleepers $\frac{\text{D. P.}}{4-41 \text{ to } 60}$.

The above experiments were repeated, keeping the pressure on for 1 hour and working up to 175 lbs. per cubic foot.

The average moisture content of the sleepers was 44 per cent. with variations from 24 per cent. to 65 per cent. and the average Specific Gravity of the timber was ·81.

The gross absorption obtained was an average of 8·6 lbs. per cubic foot which was reduced to 5·9 lbs. per cubic foot by means of a vacuum of 17 inches for ¾ hour.

Variations in individual cases were from 4·3 lbs. per cubic foot to 10·6 lbs. per cubic foot.

Sleeper number 42 which retained 10·6 lbs. of oil per cubic foot was found to be rather sappy. Oil appeared regularly throughout the wood.

Sleeper number 43 with 4·3 lbs. per cubic foot absorption, was found to have the oil in patches throughout.

Although the nett amount of oil retained was higher than in the previous experiments the variations were still present. These were probably caused either by variations in moisture content, or by some characteristic of the wood.

It was therefore decided to allow the remaining sleepers to season more thoroughly before continuing treatment.

Experiment IV.—Sleepers $\frac{\text{D. P.}}{4-61 \text{ to } 85}$.

Treatment was recommenced on June 6th after the sleepers had seasoned in the godown for a month. The average moisture content was 42·5 per cent. with variations from 21 per cent. to 60 per cent.

The actual improvement in seasoning was not very great but the individual figures were not so widely different as before.

The Specific Gravity of the wood was ·80.

The antiseptic used was a mixture of Creosote 25 per cent. and Earth Oil 75 per cent. and the Lowry Process was again used.

A pressure of 175 lbs. per sq. inch was developed in half an hour and maintained for a further hour. An average gross absorption of 8·5 lbs. per cubic foot was obtained which was reduced by a vacuum of 14 inches for 20 minutes, to an average nett retention of 6·2 lbs. of oil per cubic foot. The individual variations were from 4·6 lbs. of oil per cubic foot to 8·6 lbs. per cubic foot, being thus less marked than in previous experiments.

Sleeper number 63 with moisture content of 41 per cent., retained 6 lbs. of oil per cubic foot which completely penetrated the sleeper.

Sleeper number 76 with a moisture content of 48 per cent., retained 4·6 lbs. per cubic foot. The sapwood was completely penetrated but the penetration in the heartwood was only slight. Oil oozed from the heartwood soon after cutting so that it is fair to assume that the oil lies in pockets, and that, if left for some days, it will distribute itself more evenly throughout the timber.

Experiment V.—Sleepers $\frac{\text{D. P.}}{\text{4—85 to 109}}$.

The average moisture content was 37 6 per cent. with variations from 21 per cent. to 52 per cent. The sleepers were rapidly drying out and the moisture contents becoming less erratic.

The average Specific Gravity was ·82.

The oil used was a mixture of 25 per cent. Creosote and 75 per cent. Earth Oil injected by the Lowry Process.

A pressure of 175 lbs. per sq. inch was developed in about 20 minutes and held for forty minutes. A final vacuum of 16 inches was applied for 40 minutes.

The average gross absorption was 7·3 lbs. per cubic foot, and the average nett absorption 5·8 lbs. per cubic foot with variations from 3·3 lbs. to 9·6 lbs. in individual cases.

Sleeper number 89 with a moisture content of 24·6 per cent., retained 5·6 lbs. of oil per cubic foot and was found to be completely impregnated.

Sleeper number 107 retained only 3·3 lbs. of oil per cubic foot and on cutting was found to have the surface only treated.

Experiment VI.—Sleepers $\frac{\text{D. P.}}{\text{4—110 to 134}}$.

The average moisture content was 30·9 per cent. which varied from 23 per cent. to 48 per cent. in individual cases.

The average Specific Gravity was ·80.

The oil used was a mixture of 33 per cent. Creosote and 67 per cent. Earth Oil and treatment was by the Lowry Process.

The maximum pressure was 175 lbs. per sq. inch developed and maintained for 1 hour and followed by a vacuum of 15 inches for 20 minutes.

The average gross absorption was 9 lbs. of oil per cubic foot which was reduced by the vacuum to an average nett retention of 6·9 lbs. per cubic foot with variations from 3·6 lbs. to 11 lbs. per cubic foot.

Sleeper number 110 with moisture content of 23 per cent., retained only 3·6 lbs. per cubic foot and on cutting was found to be completely penetrated.

Sleeper number 114 with moisture content 26·5 per cent., retained 6·3 lbs. of oil per cubic foot and was completely penetrated.

Ten minutes after the pressure was put on, the wood absorbed 7 lbs. of oil per cubic foot, the pressure rising to 75 lbs.

In the next ten minutes the pressure was raised to 125 lbs. and the amount of oil absorbed was approximately 1 lb. per cubic foot whereas during the next forty minutes with the pressure rising to 175 lbs. per sq. inch, only 1 lb. per cubic foot was injected. Practically the whole of the absorption took place in the first twenty minutes with a low pressure.

Experiment VII.—Sleepers No. $\frac{\text{D. P.}}{\text{4—135 to 158}}$.

The average moisture content of the timber was 28·6 per cent. with variations from 15 per cent to 49 per cent., *i.e.*, the sleepers were much drier and more uniform as regards moisture content than in the other cases.

The Full Cell Process was employed using pure Creosote as the antiseptic oil. A preliminary vacuum of 18 inches was drawn for forty minutes followed by a pressure period of 1 hour, with a maximum pressure of 175 lbs. per sq. inch.

An average gross absorption of 12 lbs. per cubic foot was obtained which, by a slight final vacuum was reduced to an average of 10·2 lbs. per cubic foot.

Variations in individual cases were from 5 lbs. per cubic foot to 14·6 lbs. per cubic foot.

Sleeper number 135 with a moisture content of 29·9 per cent., absorbed 8 lbs. per cubic foot and was completely saturated with oil.

Sleeper number 151 with a moisture content of 15 per cent., absorbed only 5 lbs. of oil per cubic foot but was completely penetrated.

As in the former experiment, observations shewed that nearly all the absorption occurred in the early stages of the pressure period, very little entering in the last 30 minutes.

Experiment VIII.— The sleepers treated were the specimens of *Shorea assamica* (*makai*) and *Dipterocarpus pilosus* (*hollong*) belonging to the

Timber Testing Section. They were treated with Creosote by the Full Cell Process.

The average moisture content was 28·2 per cent. with individual variations from 17 per cent to 43 per cent.

The initial vacuum applied was 16 inches for 40 minutes, followed by a pressure period of one hour with a maximum pressure of 175 lbs. per sq. inch.

The average gross absorption was 10·6 lbs. per cubic foot for the two species but as the absorption for *Dipterocarpus pilosus* was higher than for *Shorea assamica*, the gross absorption for the first species alone was probably over 12 lbs. per cubic foot.

The average nett absorption for *Dipterocarpus pilosus* was 11 lbs. per cubic foot with variations from 8·6 lbs. to 12·3 lbs. per cubic foot.

Conclusions.

From the above experiments it is clear that *Dipterocarpus pilosus* (*hollong*) is capable of being made to take up a considerable quantity of oil, which in many cases saturates the sleeper.

From observations made when the timbers were sectioned it would appear that an absorption above 5 lbs. per cubic foot is sufficient to impregnate the wood throughout; with absorptions below 5 lbs. per cubic foot, the sapwood is thoroughly impregnated but the heartwood penetration is somewhat erratic.

The absorption of oil by the sleepers was somewhat variable and this appears to be due not so much to the varying moisture content as to the nature of the wood.

The wood contains a considerable quantity of resin which exudes from the wood during seasoning and probably accounts for the fact that the sleepers did not dry out or treat at all uniformly.

As in the case of *Cynometra polyandra* (*ping*) the sleepers are more likely to dry uniformly in Assam, as they will dry there more slowly than in Dehra Dun, where the climate in June is very dry and promotes rapid and uneven seasoning.

Since the wood treats erratically even when well seasoned it becomes questionable whether the Lowry Process is a safe one for this wood; on the other hand, the absorption in some cases is high and if the Full Cell Process is used, it will result in the wastage of a large quantity of oil.

It is safer, therefore, to make a compromise and use a modified Lowry Process whereby only about 25 per cent. of the gross absorption is recovered.

When Creosote alone was used a heavier absorption was obtained than with the Creosote and Earth Oil mixtures. The same was observed with *Cynometra polyandra*, which leads to the natural supposition that Creosote is the better penetrant. Whether this supposition will be borne out by later experiments remains to be seen.

It was observed that the bulk of the absorption occurred in the very early stages of the pressure period but it is desirable to make this period as long as economical for two reasons, (1) so as to keep the timber under the sterilising influence of heat for as long as possible, (2) to even up the distribution of oil throughout the timber.

The suggested specification would therefore be :—

Modified Lowry Process using a slowly built up pressure attaining a maximum of 175 lbs. per sq. inch in about 30 minutes, to be held for about 15 minutes or until an average gross absorption of 9 lbs. per cubic foot has been obtained.

A vacuum of 20 inches to 24 inches should then be applied for about 30 minutes so as to reduce the absorption to an average of 6¾ to 7 lbs. per cubic foot. The charging temperature of the oil should be about 200° F. and the retort temperature about 180° F.

The wood absorbs about 2 lbs. to 3 lbs per sleeper as the oil enters the cylinder, depending upon the time taken to fill it.

NOTE III.—Report on treatment of *Shorea assamica* (*makai*).

Two hundred metre gauge sleepers from the Lakhimpur district of Assam were received at Dehra Dun on January 1st, 1924. They were stored in a well ventilated godown for purposes of seasoning observations. On arrival they were quite green, containing 65 per cent. of moisture.

Twenty sleepers in 10 matched pairs were taken by the Timber Testing Section for the purpose of strength and spike-holding tests. Four were rejected on account of bad cracking; the remainder were marked in the usual manner under Project IV, namely $\frac{\text{S. A.}}{\text{7—1 to 176}}$ and were adzed and bored to the Assam Bengal Railway template.

The sleepers looked a very sound and promising lot, probably the best of the various species sent from Assam. The observations on seasoning in the godowns showed that very little drying if any had taken place by the end of March. Some of the sleepers were then removed to the kilns for artificial seasoning. The average moisture content of these sleepers before being put into kilns, was 70 per cent. which was reduced to 52 per cent. at the end of 14 days. Although the sleepers were drying more rapidly than in the godowns, no deterioration was obvious.

Two charges of these sleepers were treated soon after removing from the kiln. It was however decided that the sleepers had not seasoned sufficiently uniformly to warrant further treatment, which was delayed until the middle of June. On the 5th of May, the average moisture content was reduced to 35 per cent. by further seasoning in the godown whereas it was reduced to 26 per cent. by the 8th of June and 24 per cent. by July 1st.

Apart from the kiln seasoning period, the whole of the seasoning was done in the godown during the months of May and June, a little drying taking place in April.

Comparing the seasoning qualities of *Shorea assamica* with those of other Assam sleepers, it would appear that this timber is likely to give a smaller percentage of degrade in seasoning than the others with the possible exception of *Lagerstroemia Flos Reginæ and Terminalia myriocarpa*; practically no deterioration taking place when seasoned under cover.

LIFE UNTREATED.

There are no authentic records of the life of this timber untreated but, considering its abundance in Assam, it is evidently not considered to be durable as it is not used for sleeper purposes without treatment.

PREVIOUS RECORDS.

As far as can be ascertained this wood has not been treated before, hence there are no records of its life treated.

PRESENT EXPERIMENTS.

As stated above, two charges were treated immediately after their removal from the kiln but the treatment was discontinued to allow of more thorough seasoning.

Experiment I.—Sleepers No. $\frac{\text{S. A.}}{7-1 \text{ to } 20}$.

The charge was treated by the Lowry Process with a mixture of 50 per cent. Creosote, 50 per cent. Earth Oil. The maximum pressure applied was 175 lbs. per sq. inch which was kept up for 2½ hours.

This was followed by a 20 inches vacuum for ½ hour. Although the average moisture content of the charge was 36 per cent., the individual sleepers varied from 19 per cent. to 60 per cent. in moisture content.

The average Specific Gravity of the Charge was ·69.

The average gross absorption obtained was 5·41 lbs. per cubic foot which was reduced by the vacuum to an average nett absorption of 5·4 lbs. per cubic foot. This varied in individual cases from 4 lbs. to 7 lbs. of oil per cubic foot, a fairly uniform treatment.

Sleeper number 2 with a moisture content of 22 per cent., absorbed 6·6 lbs. per cubic foot. On cutting the sleeper at the rail seat it was found that the impregnation was almost complete, the penetration from the spike holes being very noticeable.

An end penetration of 10 inches was obtained and, in the middle of the sleeper, a ¾ inch penetration all round.

Sleeper number 8 with moisture content of 37 per cent., absorbed only 4 lbs. of oil per cubic foot. On cutting in the middle a ¼ inch penetration all round was observed and similarly at the rail seat. The end penetration was about 10 inches and was particularly effective round the spike holes.

Experiment II.—Sleepers No. $\frac{\text{S. A.}}{7-21 \text{ to } 40}$.

Owing to the small absorption and penetration of the previous batch it was thought advisable to treat the succeeding batches by the Full Cell Process.

The oil used was a 50-50 mixture of Creosote and Earth Oil.

The average moisture content was 29·9 per cent. with individual variations from 15 per cent. to 70 per cent. This is too great to give uniform results.

The average Specific Gravity of the wood was ·64.

The preliminary vacuum was 15 inches for 1¼ hours followed by a pressure period of 2½ hours during which time a maximum pressure of 175 lbs. per sq. inch was obtained. An average absorption of only 4·6 lbs. per cubic foot, with individual variations from 3 lbs. to 7·3 lbs. per cubic foot, was obtained.

Sleeper number 22 with a moisture content of 58 per cent., absorbed 7·3 lbs. of oil per cubic foot. On cutting this sleeper in the middle, the oil was found to have penetrated about ¼ inch all round. At the rail seat, the section was mottled throughout with oil which had penetrated about 12 inches along the grain from the end.

Sleeper number 37 with a moisture content of 66 per cent., absorbed only 3·3 lbs. per cubic foot. On sectioning the sleeper, the treatment was found to be practically a surface one. The penetration from the spikeholes was however good and the end penetration was found to be about 10 inches.

Experiment III.—Sleepers No. $\frac{\text{S. A.}}{7\text{—}41 \text{ to } 62}$.

The Full Cell Process was used with a mixture of 33 per cent. Creosote and 67 per cent. Earth Oil. A preliminary vacuum of 16 inches was applied for 40 minutes followed by a pressure period of 1 hour 35 minutes, during which time the pressure rose to a maximum of 175 lbs. per sq. inch. The average moisture content of the charge was 28 per cent. with variations from 7 per cent. to 50 per cent., both these figures being somewhat doubtful. The average absorption was 6·4 lbs. of oil per cubic foot, varying from 4 lbs. to 12 lbs. per cubic foot in individual cases.

Sleeper number 53 with an absorption of 4 lbs. of oil per cubic foot and a moisture content of 26·7 per cent., showed surface treatment only in the heartwood. The end penetration as before, was good. Sleeper number 58 with an absorption of 7 lbs. per cubic foot and a moisture content of 25·8 per cent., showed that the sapwood was completely penetrated. The heartwood was impregnated to a depth of ¼ inch and the end penetration was about 6 inches.

About 3 lbs. of oil per cubic foot were injected in the first five minutes of the pressure period, the pressure meanwhile rising to 100 lbs. per sq. inch. Still maintaining the pressure at 100 lbs. per sq. inch, about 1 lb. per cubic foot was injected in the next five minutes. During the next hour and ten minutes although the pressure rose to 175 lbs. per sq. inch only about 2·5 lbs. per cubic foot more were injected. Thus, practically all the absorption was obtained in the first hour.

Experiment IV.—Sleepers No. $\frac{\text{S. A.}}{7\text{—}63 \text{ to } 84}$.

The Lowry Process was used with a pressure of 175 lbs. for 45 minutes followed by a vacuum of 14 inches for 20 minutes, the antiseptic

being a mixture of 33 per cent. Creosote and 67 per cent. Earth Oil. The average moisture content of the timber was 26·9 per cent. with variations from 11 per cent. to 42 per cent.

The average Specific Gravity of the charge was ·67.

The average gross absorption obtained was 6 lbs. of oil per cubic foot which was reduced to 5·7 lbs. per cubic foot by the vacuum. The variations in individual cases were from 3·6 lbs. to 9·3 lbs. per cubic foot. On cutting sleeper number 72 with an absorption of 5·6 lbs. per cubic foot and a moisture content of 26 per cent., it was found that one sappy corner was completely saturated; the side penetration varied from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch with a 6 inches penetration from the ends.

Sleeper number 83 with an absorption of 4 lbs. per cubic foot, and a moisture content of 19 per cent., showed a normal side penetration of $\frac{1}{4}$ inch and an end penetration of about 6 inches.

As in the previous experiment, the wood took up from three to four pounds per cubic foot while the pressure rose to 100 lbs. per sq. inch in about 15 minutes. The remainder of the pressure period was responsible for the rest of the oil which was still slowly entering the wood at the end of the pressure period.

Experiment V.—Sleepers No. $\frac{\text{S. A.}}{7\text{—85 to 107}}$.

This batch of sleepers was treated by the Full Cell Process using Creosote as the antiseptic oil.

A preliminary vacuum of 15 inches was applied for 40 minutes followed by a pressure period of 40 minutes, during which time the pressure rose to a maximum of 165 lbs. per sq. inch.

The average moisture content of the sleepers was 21·2 per cent. with variations from 14 per cent. to 37 per cent.

The average Specific Gravity of the charge was ·67.

The average absorption was 5·5 lbs. of oil per cubic foot, varying from 1·6 lbs. to 13 lbs. per cubic foot in individual cases.

The pressure in this experiment was not kept on sufficiently long to ensure that refractory specimens had taken up as much oil as they could be made to do, hence the wide variation in absorption in individual sleepers. In fact, over 1 lb. of oil per cubic foot was still going into the timber in five minutes, when the pressure had to be discontinued owing to a breakdown in the plant.

Sleeper number 86 with a moisture content of 17 per cent., absorbed only 3 lbs. per cubic foot. The penetration was only a little more than $\frac{1}{16}$ inch on the side and 4 inches on the end.

Sleeper number 107 absorbed 5·6 lbs. per cubic foot, with a moisture content of 13·8 per cent. The sapwood was completely penetrated but

the heartwood only to a maximum depth of ¼ inch. The end penetration was satisfactory.

The pressure was raised slowly during the experiment. During the first five minutes a little more than 1 lb. per cubic foot was absorbed with the pressure at 10 lbs. only. In 30 minutes, the pressure had risen to 100 lbs. during which time the absorption was just under 5 lbs. of oil per cubic foot. During the next ten minutes the absorption was about 1 lb. per cubic foot and the pressure had risen to 150 lbs. per sq. inch. The wood was thus still taking the oil when the pressure had to be discontinued.

The penetration of oil into wood always lags behind the pressure and it is necessary, in order to obtain maximum penetration, to keep on the pressure for some time after the maximum absorption has been reached.

In this experiment. oil was still going into the wood when the pressure was released and therefore maximum penetration had not been obtained.

Experiment VI.—Sleepers No. $\frac{\text{S. A.}}{\text{7—108 to 129}}$.

This experiment was a duplicate of Experiment V but a pressure of 150 lbs. only was developed for twenty minutes.

The average moisture content was 30·1 per cent. with variations from 14 per cent. to 50 per cent. The average Specific Gravity of the timber was ·67. In this experiment, as in the last, oil was still entering the wood at a rate of about 1 lb. per cubic foot every five minutes, when the pressure was stopped.

The average absorption was 6 lbs. per cubic foot which could have been appreciably increased by a longer pressure period. Individual variations ranged from 2·6 lbs. per cubic foot to 12 lbs. per cubic foot.

Sleeper number 119 with a moisture content of 35·4 per cent., absorbed only 2·6 lbs. per cubic foot which gave a surface treatment only. Sleeper No. 129 with a moisture content of 50 per cent., absorbed 6 lbs. per cubic foot. The sapwood was completely penetrated but the heartwood surface was affected to a depth of ¼ inch only.

Experiment VII.—Sleepers No. $\frac{\text{S. A.}}{\text{7—130 to 152}}$.

The oil used was a mixture of 25 per cent. Creosote and 75 per cent. Earth Oil injected by the Full Cell Process.

The initial vacuum was 16 inches for 55 minutes followed by a pressure period of 100 lbs. for 45 minutes.

The average absorption was 4·8 lbs. per cubic foot with variations from 2·6 lbs. per cubic foot to 10·3 lbs. per cubic foot.

The average moisture content was 20·4 per cent. with variations from 11 per cent. to 28 per cent.

Much the same remarks apply to this experiment as applied to Experiments VI and V namely, that the pressure was not sufficient nor applied for a sufficiently long period to ensure satisfactory results.

Sleeper number 139 with a moisture content of 18·9 per cent., absorbed 4·6 lbs. per cubic foot. The sapwood was completely penetrated but the heartwood was impregnated to a depth of only ½ inch or so.

Experiment VIII.—Sleepers No. $\frac{\text{S. A.}}{\text{7—153 to 173 and 143}}$.

The oil used was a mixture of 25 per cent. Creosote and 75 per cent. Earth Oil injected by the Lowry Process. The maximum pressure attained was 175 lbs. per sq. inch of 1¼ hours duration.

This was followed by a vacuum of 15 inches for 20 minutes.

The resulting nett absorption was 4·9 lbs. per cubic foot, which varied in individual cases from 2·3 to 7·3 lbs. per cubic foot.

The average moisture content was 26·8 per cent. with variations from 16 per cent. to 33 per cent. in individual cases.

The average Specific Gravity of the charge was ·70.

Sleeper number 163 with a moisture content of 25 per cent., absorbed 2·3 lbs. per cubic foot. A surface treatment only was obtained. Sleeper number 156 with a moisture content of 22·9 per cent., absorbed 4·6 lbs. per cubic foot. The penetration on the side was found to be ⅛ inch and on the end 8 inches.

The maximum pressure in this experiment was reached in about 40 minutes. After one hour, no more oil was entering the wood and the pressure was discontinued after a further 15 minutes.

CONCLUSIONS.

From the above experiments it is apparent that *Shorea assamica* is not an easy wood to treat, at least uniformly; but it will be apparent on scrutinising the experimental data that more uniform results were obtained with long pressure periods than with short periods, although the average absorptions do not differ greatly in the two cases.

Again, no rule with regard to moisture content can be deduced from the behaviour of these sleepers. As in previous experiments on other species, some sleepers with a moisture content of over 30 per cent. were satisfactorily impregnated and *vice versâ*. As pointed out in a preceeding note this is rather contrary to accepted theories, but it may well be that since our method of determination of moisture content rejects the first layer to a depth of ½ inch, the surface of the sleeper may be much drier than is indicated by the percentage moisture content of the interior which is the portion explored by our method of taking borings.

The most striking thing in these experiments was the condition of the sleeper at the rail seat when adzed and bored before treatment. Even with an average absorption of 3·3 lbs. per cubic foot the penetration from the spike holes was sufficient to give good protection at this important point. The penetration from the ends of the sleeper is in the neighbourhood of 6 inches and this fact should be taken advantage of by adzing and boring before treatment.

As in previous experiments, the treatment with Creosote only, showed that wood is more easily penetrated by this oil than by the mixtures, but unfortunately no data were obtained to show the maximum average amount which could be injected.

The results show that impregnations under 5 lbs. per cubic foot are not satisfactory, as even with heavier impregnation the side penetration is only about ¼ inch. Some specimens are capable of taking up a good deal more than this and a 7-lb. treatment gives satisfactory results.

For the present therefore, the Full Cell Process is advised, using a preliminary vacuum of 20 inches to 24 inches for ¾ hour.

The pressure should reach its maximum in about one hour, and be kept on until an average absorption of at least 6·5 lbs. per cubic foot is obtained. The probable time will be in the neighbourhood of two hours so that not more than 3 charges per day of 10 hours could be got through on a commercial scale. With regard to moisture content it is advisable to season until this is below 30 per cent. Such a moisture content can be attained even in a dry climate without deterioration provided the timber is not exposed to the sun.

NOTE IV.—A note on the treatment of *Dillenia indica* (*otenga*).

Two hundred metre gauge sleepers of *Dillenia indica* (*otenga*) were received from the Sibsagar Division of Assam on the 2nd January 1924.

These were marked in accordance with Project IV, *viz.*, $\frac{}{59}\ \frac{\text{D. I.}}{\text{upwards}}$.

Ten sleepers were rejected on arrival on account of bad cracking. From the remainder, twenty sleepers in ten matched pairs were handed over to the Timber Testing Section for experiment. The odd numbers were then piled in the godown in open crib and the even numbers in closed crib for seasoning observations.

During the months of January, February, March and April the sleepers seasoned very slowly, losing on an average 1½ per cent. of moisture per month. During May, the rate of seasoning increased to 20 per cent. with the result that about 20 sleepers were rejected on account of bad splits. This result seemed to be independent of the two methods of piling, shewing that both are much too open for the hot weather.

The even numbers were removed to the Tiemann kiln in the early part of June.

The moisture content was reduced from 59 per cent. to 29 per cent. in 32 days without any degrade.

The odd numbers were afterwards dried in the same manner from 44 per cent. to 29 per cent. in 18 days with perfect safety.

It is therefore apparent that the wood dries rapidly in a hot dry atmosphere but is liable to crack unless the rate of drying is properly controlled.

It is advisable on this account to pile the sleepers in close formation, allowing about an inch of space between successive sleepers in the layer and protecting the piles from the direct rays of the sun.

LIFE UNTREATED.

From authentic records of the behaviour of untreated sleepers of this species it appears that the wood is not durable in the track, the average life being about 3 years.

PREVIOUS RECORDS OF TREATMENT.

In 1915, the Forest Economist carried out experiments on the treatment of this species with a mixture of 45 per cent. Creosote and 55 per cent. Earth Oil in open tanks. The sleepers were afterwards laid in the Assam Bengal Railway.

The sleepers absorbed about 9 lbs of oil per cubic foot on the average and when last inspected, after eight years' service, showed that 70 per cent. were still sound.

Detailed reports however, show that deterioration in the majority of cases is due to cracking and a longer life than 12 years is not anticipated on this account.

PRESENT EXPERIMENTS.

Experiment I.—Even numbers from $\frac{\text{D. I.}}{59\quad 8}$ to $\frac{\text{D.I.}}{59-58}$ except 14, 20, 24 and including $\frac{\text{D. I.}}{59\quad 4}$.

The sleepers were treated with 25 per cent. Creosote and 75 per cent. Earth Oil by the Full Cell Process. The average moisture content of the sleepers was 9·5 per cent. with variations from 5 per cent. to 24 per cent. in individual cases.

The average Specific Gravity of the wood was ·60.

The initial vacuum was 18 inches for one hour followed by a pressure period of one hour during which time the pressure rose to 175 lbs. per sq. inch.

The average absorption was 19 lbs. of oil per cubic foot with variations from 7 lbs. to 26 lbs. per cubic foot. Sleeper number 10 on being cut shewed complete penetration The moisture content was 4·8 per cent. and the nett absorption 7 lbs. per cubic foot.

The pressure was raised slowly and evenly throughout the treatment but, in the first five minutes, while the pressure rose to 10 lbs. per sq. inch, approximately 9 lbs. of oil per cubic foot were injected. The rate subsequently fell off until during the last five minutes the oil was being pressed in at the rate of about ·25 lbs. per cubic foot.

The wood however, was not impregnated to refusal.

Experiment II.- Even numbers $\frac{\text{D. I.}}{58\quad 10}$ to $\frac{\text{D. I.}}{59-10}$. The oil used was a mixture of Earth Oil and Creosote in the proportions of Creosote 33 per cent. to Earth Oil 67 per cent. and was injected by the Lowry Process.

The average moisture content of the sleepers was 10·5 per cent. with variations from 4·4 per cent. to 17·6 per cent.

The average Specific Gravity of the wood was ·60.

The pressure was raised to 175 lbs. per sq. inch during 1 hour and was followed by a vacuum of 16 inches for 40 minutes. The nett absorption was on an average 18·8 lbs. per cubic foot with variations from 12 lbs. to 25 lbs. Considering that the minimum absorption was 12 lbs. per cubic foot no sleepers were cut open as the impregnation was undoubtedly complete.

Within five minutes of the application of pressure, about 7 lbs. of oil per cubic foot was absorbed, the pressure rising to 10 lbs. per sq. inch. During the next 5 minutes, a similar amount was absorbed, the pressure rising to 50 lbs. per sq. inch. The rate then gradually fell off until, in the last 5 minutes with the pressure at 175 lbs. per sq. inch, less than 1 lb. of oil per cubic foot entered the wood. It was not however treated to refusal.

Experiment III.—Even numbers $\frac{\text{D. I.}}{59\text{—}110 \text{ to } 158}$ except $\frac{\text{D. I.}}{59\text{—}112}$.

The antiseptic used was a mixture of 50 per cent. Creosote and 50 per cent. Earth Oil injected by the Lowry Process.

The moisture content averaged 10·3 per cent. with variations from 8·2 per cent. to 15 per cent.

The pressure was raised to 95 lbs. per sq. inch in 9 minutes and was followed by a vacuum of 15 inches for 40 minutes.

During the pressure period the nett absorption was an average of 13·7 lbs. of oil per cubic foot with variations from 4·6 lbs. to 24 lbs. per cubic foot.

Sleeper number 122 on being cut showed that an absorption of 6·3 lbs. per cubic foot gave complete penetration.

This experiment together with the previous ones, supports the contention that the bulk of the absorption takes place in the first few minutes.

Experiment IV.—Odd numbers $\frac{\text{D. I.}}{59\text{—}1 \text{ to } 49}$ excluding 19 and 21.

A mixture of 25 per cent. Creosote and 75 per cent. Earth Oil was used as an antiseptic, impregnation being by the Lowry Process.

The average moisture content of the batch was 12·7 per cent. with variations from 5·8 per cent. to 18·9 per cent.

As before the average Specific Gravity of the charge was ·60.

Impregnation was finished in 8 minutes under a pressure of 50 lbs. per sq. inch followed by a vacuum of 16 inches for 28 minutes.

The average absorption was 9·8 lbs. per cubic foot with variations from 5·6 lbs. per cubic foot to 15·3 lbs. per cubic foot.

Sleeper number 23 with a moisture content of 8·3 per cent., absorbed 12 lbs. per cubic foot and was seen to be completely penetrated.

Experiment V.—Odd numbers $\frac{\text{D. I.}}{59\text{—}51 \text{ to } 101}$ except 56 and 65.

The antiseptic used was a mixture of 33 per cent. Creosote and 67 per cent. Earth Oil injected by the Lowry Process. The average moisture content of the charge was 17·4 per cent. with variations from 13 per cent. to 23 per cent. The average Specific Gravity of the charge was ·60.

The pressure employed was 25 lbs. per sq. inch for 10 minutes followed by a vacuum of 15 inches for 30 minutes. During this time the

timber absorbed an average of 9·5 lbs. of oil per cubic foot which varied from 6·3 lbs. to 13·6 lbs. per cubic foot in individual cases.

From previous experiments it is seen that 6 lbs. of oil per cubic foot penetrate the whole of the sleeper so that it was not necessary to cut these sleepers nor those in subsequent experiments.

Experiment VI.—Odd numbers $\frac{\text{D. I.}}{59-103 \text{ to } 151}$ except 105 and 111. The antiseptic used was a mixture of 50 per cent. Creosote and 50 per cent. Earth Oil injected by the Lowry Process.

The average moisture content was 19·3 per cent. with variations from 13·4 per cent. to 30 per cent. The Specific Gravity was ·60.

The pressure was raised to 25 lbs. in 5 minutes followed by a vacuum of 16 inches for 45 minutes. During the pressure period the amount of oil absorbed was 9·1 lbs. per cubic foot on the average, varying from 6·3 lbs. to 12·3 lbs. per cubic foot. This quantity of oil is sufficient to impregnate the sleeper throughout.

Experiment VII.—Sleepers number $\frac{\text{D. I.}}{59-158, 155, 157, 159 \text{ to } 165}$ and Timber Testing Specimens 1 to 10. The oil used was Creosote injected by the Lowry Process.

The pressure used was 15 lbs. per sq. inch for 25 minutes followed by vacuum of 15 inches for 30 minutes. The resulting absorption was an average of 10·7 lbs. per cubic foot with variations from 6·3 lbs. to 14·6 lbs. per cubic foot.

The moisture content averaged 15·7 per cent. with variations from 10·8 to 23·5 per cent.

CONCLUSIONS.

It will be observed that the average moisture content altered slightly during the course of the experiments which were started just as the rains commenced.

The maximum moisture content however was not raised showing that only the drier members absorbed moisture. As the humidity was at times 100 per cent. and never lower than 80 per cent., it would appear that it is quite possible to season wood to below 30 per cent. even in the wettest climate, although the process may be a slow one.

From the experiments, it is obvious that it is a very simple matter to treat *Dillenia indica* to refusal under pressure, and that, long before the point of refusal is reached, the wood is saturated with oil. Even with less than 6 lbs. of oil per cubic foot the wood appears to be impregnated throughout.

The difficulty seems to be to control the amount injected, for, since the wood is impregnated throughout, the oil is not drawn out by the final vacuum, there being no air present in the cells to force it out.

The wood offers a chance of success for the Rueping Process as this process would undoubtedly recover a large percentage of oil even though the gross absorption was heavy.

Again, since the wood is so easily treated it is not an economic proposition to allow the wood to remain in the oil sufficiently long to become sterilised. This however is offset by the complete impregnation which would prevent any development of fungus even if the wood were previously infected. Moreover, since the mechanical life of the wood does not appear to be more than 12 years it would probably be safe to employ a mixture containing less Creosote and give the wood a fairly heavy treatment.

The specification for treatment would therefore be—

Process :—Lowry with highest recovery possible, *viz.*, vacuum of 24 inches for 45 minutes.

Gross Impregnation.—10 lbs. per cubic foot with possible recovery to 7 lbs. per cubic foot. The pressure should not exceed 15 lbs. per sq. inch which should prove sufficient for injecting the required amount of oil in 30 minutes. The total treating period should not exceed 1 hour 30 minutes which would give 5 charges per working day. If the Rueping Process is employed a preliminary air pressure of 60 lbs. per sq. inch should be developed and a gross absorption of 10 lbs. per cubic foot aimed at. Probably the final vacuum could be dispensed with as the imprisoned air would expand sufficiently to reduce the nett absorption to 7 lbs. per cubic foot.

NOTE V.—Report on treatment of *Bischofia javanica* (*uriam*).

Two hundred metre gauge sleepers of this species were sent from the Sibsagar division of Assam, for treatment according to Project IV.

They arrived on January 2nd, 1924, at Dehra Dun, and were, after rejecting the badly cracked sleepers, marked and stacked in two piles in a roofed well-ventilated godown.

On inspection, they appeared to be fair specimens for the species but had developed, either in transit or in the jungle after conversion, a certain number of cracks.

Twenty specimens, in ten matched pairs, were handed to the Timber Testing Section for mechanical tests on the treated and untreated sleepers. Ten were tested untreated ; the remaining ten were treated with pure Creosote and returned to the Timber Testing Section.

About thirty of the sleepers were rejected as being unfit for use on account of bad longitudinal cracking which seems to be characteristic of the species. The remainder were marked according to a scheme, by which the first letters of the botanical name were cut on one broad surface towards the heart. Under these letters were cut the serial number of the species according to Project IV and the individual number of the sleeper, *viz.*, $\frac{\text{B}}{30}\frac{\text{J.}}{1 \text{ to } 150}$. They were adzed and bored before treatment.

The average moisture content on arrival was about 95 per cent., the sleepers being thus quite green. These sleepers were seasoned under the same conditions as the other Assam sleepers, until their moisture content went down to 18 per cent. by the end of June.

On 3rd July, all the sleepers, except sleepers 1-36, were transferred to the Tiemann seasoning kiln. They were kept for 22 days in the kiln, in which time, the moisture content was reduced from 18 per cent. to 9·6 per cent. They were then taken back to the godown and allowed to air-season again for about 10 days prior to treatment. During this period, due to the high humidity prevailing, the wood absorbed moisture again, but the distribution of moisture in the cross-section of the sleepers tended to become more uniform.

It was decided to commence treatment on 13th August, by which time the moisture content went up nearly to 20 per cent. The seasoning was very rapid in June. As the moisture contents of the individual sleepers of the first charge appeared to be fairly uniform, treatment of this species was continued.

Recapitulating, it may be stated that from the beginning of January till the end of April, only about 40 per cent. of the moisture was lost,

At the beginning of June, the moisture content was about 40 per cent. and it came down to about 18 per cent by the end of June. During the ten days the sleepers were in the godown, prior to treatment, the moisture content of the sleepers became uniform at about 15 per cent. to 20 per cent.

The evaporation in June was obviously too rapid for this timber which has a tendency to crack badly and hence, *uriam* sleepers should be close piled during the dry season. The total degrade, under the conditions described above, was about 17·5 per cent. It should be noted that under these conditions no sleepers were rejected owing to fungus or borer attack as they were stacked in a roofed godown on elevated tarred paving block flooring. It may be mentioned that the degrade was not augmented by kiln seasoning as the rate of evaporation is controllable in a kiln, and it was kept deliberately low, as shown by a reduction in moisture content of only 6 per cent. in 22 days.

LIFE UNTREATED.

Authentic records of the life of this timber, untreated, are rather meagre; it has never been used on a large scale for railway sleepers except in upper Assam. The untreated life of this sleeper is about 5 years.

The timber is not regarded as durable in exposed positions, and it has, like the members of the *Terminalia* family, the tendency to crack badly. But the oil treatment of well-seasoned sleepers, due to the waterproofing action obtained, is expected to reduce the tendency to check and split.

PREVIOUS RECORDS.

This wood does not appear to have been treated so that no records of treated life are extant. *See* Indian Forest Records, Vol. VI, Pt. IV, page 85 for a very small experiment.

PRESENT EXPERIMENTS.

Treatment was commenced on 15th August 1924.

Details of chemical analyses of the Creosote and Earth Oil, used in the experiments, are appended to this report. See Appendices A and B.

For details of the present experiments, *vide* Appendix V.

Experiment I.—Sleepers $\frac{\text{B. J.}}{30-1 \text{ to } 25}$ Nos. 6, 7 and 17 were rejected owing to bad cracks. The sleepers were treated with a 50 per cent. mixture of Creosote and Earth Oil by the Full Cell Process.

The average Specific Gravity of the wood, corresponding to an average moisture content of the charge of 19 per cent., was ·68.

The moisture content varied, in individual cases, from 13 per cent. to 28 per cent.

A pressure of 175 lbs. per sq. inch was developed in 30 minutes, and maintained for a further 1 hour and 20 minutes. During the last 50 minutes of the pressure period, there was practically no absorption. The gross absorption was 6·0 lbs. per cubic foot.

A vacuum of 13 inches for 20 minutes was afterwards developed in the cylinder, reducing the average nett absorption to 5·4 lbs. per cubic foot, with variations in individual cases from 2 lbs. to 9·7 lbs. per cubic foot.

Sleeper number 1, with moisture content 16·8 per cent., was cut at the rail seat, and it was found to have all the sapwood, which was 40 per cent. of the cross section, completely impregnated. The heartwood had absorbed practically nothing, the end pentration hardly amounting to an inch. This sleeper had retained 7·3 lbs. per cubic foot.

Sleeper number 9, with a moisture content 21·6 per cent., was cut in a similar way and it was found again that only the 30 per cent. sapwood portion of the sleeper had absorbed oil, there being practically no penetration into the heartwood. This sleeper had retained 5·7 lbs. per cubic foot, which is about the average figure for the charge. This average figure, from the absorption point of view, affords no clue whatever to relative penetration but it is more an index of the average percentage of sap-wood in the sleepers of a charge of this wood.

Sleepers number 14 and 21, with average moisture contents of 19·1 per cent. and 21·8 per cent. respectively, were cut at the rail seat. The former had absorbed 9·7 lbs. per cubic foot, consisting as it did of 60 per cent. sapwood, which was completely saturated. The latter had absorbed only 2 lbs. per cubic foot, the poor absorption being explained by the low proportion of sapwood it contained.

Experiment II.- Sleepers $\frac{\text{B. J.}}{30-17 \text{ to } 48}$.

The same oil as in Experiment I was used, but the sleepers were treated by the Lowry Process.

A pressure of 175 lbs. per sq. inch was developed in 25 minutes, and maintained for a further 1½ hours; the final vacuum was 13 inches for 20 minutes.

The average gross absorption was 6·7 lbs. per cubic foot.

The average Specific Gravity of the wood was ·64, corresponding to an average moisture content of 16·9 per cent., with variations in individual cases from 11·7 per cent. to 25·7 per cent.

The average nett absorption was 4·2 lbs. per cubic foot, varying from 1·0 lb. to 7·7 lbs. per cubic foot, the absorptions being very erratic as in

Experiment I, not due to variations in moisture content, but to the different proportions of sapwood in the various sleepers of the charge.

Sleepers number 29 and 32 were cut at the rail seat and the heartwood was found to have absorbed practically nothing. No. 29, moisture content 12·3 per cent., absorption 7·7 lbs. per cubic foot, had 50 per cent. sapwood and No. 32, moisture content 25·7 per cent., absorption 5·7 lbs., had 25 per cent. sapwood.

Sleepers number 41 and 46 with absorptions of 1·3 lbs. and 2·7 lbs. per cubic foot (below the average figure for the charge), were similarly cut open and the penetration examined. The former had no sapwood and the latter contained 10 per cent. sapwood which had oil throughout.

Experiment III.—$\frac{\text{B. J.}}{\text{10—49 to 71}}$.

Sleepers number 62, 66 and 69 were rejected owing to cracks.

The oil used was a mixture of 1 part of Creosote with 2 parts of Earth Oil. The sleepers were treated by the Full Cell Process. They got wet just prior to treatment, during transit from the godown to the laboratory.

The average Specific Gravity was ·65 corresponding to an average moisture content of 18·3 per cent. with variations from 13 per cent. to 24·3 per cent. in individual cases.

A pressure of 175 lbs. per cubic foot was developed, very gradually, in an hour, and maintained for a further ten minutes. It should be observed that all the absorption took place within the first 10 minutes of the pressure period, under a pressure of 50 lbs. per sq. inch ; in the subsequent 65 minutes at higher pressures, there was not even a gallon of absorption by the whole charge of sleepers.

The average gross absorption of the charge was 3·5 lbs. per cubic foot. A vacuum of 18 inches for 15 minutes, was applied subsequently, and the average nett absorption amounted to 3·14 lbs. per cubic foot, with variations from nothing to 8 lbs. per cubic foot.

Six out of the twenty sleepers of the charge retained one pound or less per cubic foot, two of them absorbing nothing. Sleepers 68 and 50 were cut open, as before. The former, with a moisture content of 17·9 per cent., had retained 8 lbs. per cubic foot, and the latter, with a moisture content of 18·4 per cent., had 6 lbs. per cubic foot. Sleeper No. 68 had 60 per cent. sapwood which was completely impregnated ; in the heartwood, however, there was no oil.

Sleeper number 50, with 40 per cent. sapwood, showed a similar result.

Sleepers number 60 and 65, retaining 4·3 lbs. and 2·0 lbs. per cubic foot respectively, were also cut open, and the same phenomenon observed. only the 5 per cent. sapwood of the former absorbing oil, and

the latter with practically no sapwood, showed a low absorption and surface treatment only.

The moisture content of the two sleepers was 22·0 per cent. and 17·6 per cent. respectively.

Experiment IV.—Sleepers $\frac{\text{B. J.}}{0\ \ 72 \text{ to } 96}$.

Sleepers number 84 and 86 were rejected owing to bad longitudinal cracks. Sleepers number 81 and 87 were also cracked rather badly.

The average Specific Gravity of the wood was ·64, corresponding to an average moisture content of 14·8 per cent., varying in individual cases from 11·5 per cent. to 21·9 per cent.

The same oil as that used in Experiment III was used, but the sleepers were treated by the Lowry Process.

A pressure of 175 lbs. per sq. inch was developed in about 25 minutes, and maintained for a further 45 minutes; a final vacuum of 16 inches for 25 minutes, was applied.

The gross absorption was 6·3 lbs. per cubic foot. and the average nett absorption was 4·3 lbs. per cubic foot, with variations from 1 lb. to 7 lbs. per cubic foot in individual cases.

Sleepers number 81, 87 and 91 were cut open. They had retained 1·0 lb., 8·3 lbs., and 6·0 lbs. per cubic foot respectively, at moisture contents of 18·4 per cent., 11·5 per cent., and 10·6 per cent.

The first sleeper, as might be expected, had the least proportion of sapwood (about 3 per cent.). The second and third had 50-60 per cent. sapwood, which alone was impregnated with the oil.

The heartwood penetration, in all cases, was practically nil, and the end penetration was hardly an inch.

Experiment V.—Sleepers $\frac{\text{B. J.}}{8\text{ I }\ 97 \text{ to } 119}$.

Except sleeper number 119, all the sleepers of this charge were fairly good.

The average Specific Gravity was ·64, corresponding to an average moisture content of 17·4 per cent.; the moisture content varied, in individual cases, from 7·5 per cent. to 36·4 per cent.

The oil used was a mixture of one part of Creosote and three parts of Earth Oil; the sleepers were treated by the Lowry Process.

A pressure of 175 lbs. per sq. inch was developed in 40 minutes, and maintained for a further 10 minutes, the absorption being nil during the later half of the pressure period.

The gross absorption was 5·5 lbs. per cubic foot. A final vacuum of 17 inches for 20 minutes, was applied, reducing the average nett absorption to 4·5 lbs. per cubic foot with variations from 1·7 lbs. to 9·0 lbs. per cubic foot, the absorptions being, it is almost unnecessary to reiterate,

very erratic and in each case being proportional to the percentage of sapwood in the sleeper.

Sleeper number 99, with an absorption of 6·0 lbs. per cubic foot, on being cut was found to have 40 per cent. sapwood which was completely impregnated while the heartwood had practically no oil. The moisture content of the sleeper was 14·3 per cent. Sleeper number 119 was also cut, and similar results were noticed—the 10 per cent. sapwood portion absorbing all the oil, 2·7 lbs. per cubic foot, at 13·4 per cent. moisture content.

Experiment VI.—Sleepers $\frac{\text{B. J.}}{30\text{—}120 \text{ to } 142}$.

Sleepers number 124, 129 and 140 were rejected owing to their being badly cracked ; the others were in a fairly good condition.

The average Specific Gravity of the wood was ·67, corresponding to an average moisture content of 16·5 per cent. The moisture content varied, in individual cases, from 11·3 per cent. to 25·2 per cent.

Pure Creosote was used for treatment, and the Lowry Process was adhered to.

A pressure of 175 lbs. per sq. inch was developed in 15 minutes and maintained for a further 45 minutes, till a gross absorption of about 6·5 lbs. per cubic foot was obtained.

A final vacuum of 15 inches for 20 minutes was applied. The average nett absorption was 5·1 lbs. per cubic foot, varying in individual cases from 1·3 lbs. to 12·0 lbs. per cubic foot.

The absorption was very erratic, as before. Sleepers number 126, 136 and 139 were cut open with the following results :—

No. of Sleeper.	Absorption per cu. ft.	Moisture Content. per cent.	Sapwood. per cent.	Absorption.
126. .	6·0	19·4	45	In each case, the impregnation was confined to the sapwood portion.
136. .	3·0	19·0	15	
139. .	10·8	14·8	60	

Experiment VII.—Sleepers $\frac{\text{B. J.}}{30\text{—}143 \text{ to } 150}$ except 148 and 149 and 10 *Bischofia javanica* Timber Testing Section sleepers.

Sleeper 149, being badly cracked, was rejected. The average Specific Gravity of the wood was ·67, corresponding to an average moisture content of 21·8 per cent. The moisture content varied, in individual cases, from 13·5 per cent. to 38·7 per cent.

The same antiseptic and process, as those in Experiment VI, were adhered to.

A pressure of 175 lbs. per sq. inch was developed in 40 minutes, and maintained for a further 20 minutes, during which time there was no further absorption.

A gross absorption of about 5 lbs. per cubic foot was secured, and, with a vacuum of 16 inches for 20 minutes, was reduced to an average nett absorption of 4·1 lbs. per cubic foot with variations, in individual cases, from 1·0 lb. to 9·0 lbs. per cubic foot.

Sleeper number 143 was cut open. There being no sapwood, as might be expected, there was practically no penetration into the sleeper. It had retained only 1·0 lb. per cubic foot at a moisture content of 18·1 per cent.

CONCLUSION AND RECOMMENDATIONS.

From the above experiments, it is clear that the heartwood of *uriam* is very refractory to pressure treatment with Creosote or Earth Oil, whereas the sapwood absorbs the oils very readily at low pressures.

More than 80 per cent. of the absorption, in almost all the experiments with this wood, took place in the first 10 minutes of the pressure period (under 50 lbs. per sq. inch.) The heartwood, even after a two hours' treatment at high pressures, with the charging oil at about 200°F., received but a surface treatment.

From observations made, it would appear that the absorptions by this wood are very erratic, as they seem to bear a direct relation to the sapwood content in each case. It is well nigh impossible to grade sleepers of this wood according to the percentage of sapwood, as can be done in the case of the pines, etc., since it is difficult to see the difference between sapwood and heartwood. Under these circumstances, the only precaution that can be taken with advantage is to adze the sleepers on their broad faces (nearest to the pith, as indicated by the orientation of the annual rings) prior to treatment. Sleepers should also be bored before treatment. Fluctuations in moisture content below the fibre saturation point (about 28 per cent.) appear to have no corresponding bearing on absorptions.

Though there is practically no further absorption of oil by this badly tylosed and resin occluded wood, after the impregnation of the sapwood, a two hours' pressure treatment is recommended. This will keep the timber under the sterilizing influence of heat at a temperature superior to 50°C., and will enable the Creosote to explore the small surface crevices and cracks.

The most important point to bear in mind, when treating this wood or using treated *uriam* sleepers; is to see that the sleepers are laid in the permanent way with the heart side up so that the well-impregnated and more water-proof sapwood has a chance to resist the agents of destruction; at the same time, the stronger heartwood is presented to resist rail-cutting, spike-kill, etc.

The suggested specification for the treatment of this wood would therefore be :—

Modified Lowry Process using a slowly built up pressure attaining to a maximum of 175 lbs. per sq. inch in about one hour, and held for a further one hour followed by a vacuum of 20 inches to 24 inches for about 25 minutes, so as to reduce the gross absorption by about 30 per cent.

The charging temperature of the antiseptic should be about 200°F. and the retort temperature about 180°F.

The reason for advising the Lowry Process in connection with this wood is, that the only portion capable of treatment is the sapwood which, if treated by the Full Cell Process, would retain more oil than is necessary for its preservation. By using the Lowry Process, surplus oil is recovered and the treatment is more economical.

NOTE VI. Report on treatment of *Terminalia myriocarpa* (*hollock*).

One hundred and ninety three M. G. sleepers of this species were sent from the Lakhimpur Division, Assam, for treatment according to Project IV.

They arrived on January 10th 1924, and were stacked in two piles, after marking, in a roofed well-ventilated godown with an elevated wood-block paved floor.

On close inspection, they were found to be in very fair condition but had developed, either in transit or in the jungle after conversion, a certain number of cracks.

Twenty sleepers, in ten matched pairs, were handed to the Timber Testing Section for mechanical tests in a treated and untreated state. Ten were tested untreated, the other ten being kept by the Timber Testing Section until required for treatment by the Wood Preservation Section. After treatment with pure creosote, they were returned to the Timber Testing Section.

Eleven of the sleepers, were rejected as being unfit for use on account of cracks, knots near rail-seat, etc.

The remainder were marked according to a scheme by which the first letters of the botanical name were cut on one broad surface on the heart side. Below these letters were cut the serial number of the species, and the individual number of the sleeper, *e.g.*, $\frac{\text{T. M.}}{1 \text{ to } 162}$. They were adzed and bored before treatment.

The average moisture content when received was about 125 per cent., the sleepers being thus quite green.

These sleepers were seasoned under the same conditions as the *ping*, (*Cynometra polyandra*), *hollong*, (*Dipterocarpus pilosus*) and *makai* (*Shorea assamica*), until their moisture content had dropped to 94·5 per cent., when 122 sleepers were transferred to the Tiemann seasoning kiln, in order to expedite the seasoning process, and make them ready for treatment under pressure.

They were kept for about 55 days in the kiln, in which time, the moisture content was reduced to 65 per cent. in the centre, and case-hardening was thought to have set in as the exterior was much drier. They were then removed to the godown, and allowed to air season in two piles, one half piled in open crib and the other half in closed crib formation.

It was decided to commence treatment on 1st July, by which time, the moisture content was about 20 per cent. The seasoning was very rapid in June, and, as the moisture contents of the individual sleepers of the first charge appeared to be fairly uniform, treatment of the species

was continued. Recapitulating, it may be stated that from the beginning of January till the end of March, only about 30 per cent of moisture was lost. Two months in the kiln reduced the moisture percentage by another 30 per cent., or possibly a little more, as only the interior of the sleepers was wet; on allowing the sleepers to stand in the godown, the moisture content evened down to about 20 per cent. after a month, so that in the dry month of June, the evaporation amounted to about 35 per cent. This caused a slight opening of the timber, and may be reckoned to be a more rapid rate for air drying than is safe with such dense hardwoods.

The kiln seasoning rate had to be necessarily slow as the kiln was packed with sleepers of *Dillenia indica* (*otenga*) some of which were badly cracked, and of *Terminalia myriocarpa* (*hollock.*)

With the one month of air drying in the godown, the moisture content evened down and case-hardening was not noticeable at the time of treatment.

LIFE UNTREATED.

Authentic records of the life of this timber, untreated, are rather meagre. In November 1915, 22 untreated sleepers of *hollock* were laid in the Assam-Bengal Railway. They gave a life of 5 years, almost the same as that of *sain* (*Terminalia tomentosa*) untreated.

The timber is not regarded as durable in exposed positions, and it has, in common with the other members of the *Terminalia* family, the tendency to crack rather badly. The oil treatment of well-seasoned sleepers is expected to reduce this tendency.

PREVIOUS RECORDS.

In 1915, 8 M. G. sleepers were treated in open tanks with a mixture of Green Oil and Liquid Fuel Oil, in the proportion of 9 to 11.

They absorbed 2·0 lbs. per cubic foot (so that it was only a surface treatment) and were laid in the Assam-Bengal Railway in November of the same year. At the inspection of January 1925 all the 8 sleepers were in good condition (A class) after 9 years' service in the line.

89 M. G. sleepers treated under pressure with the same oil as that referred to above, absorbed 4·0 lbs. per cubic foot on the average and were laid in the same railway in December 1915.

In January 1925, 51 were classed as A, 17 as B, 7 as C, and 14 had been rejected. Due to rail creep, a certain amount of 'spike killing' was also observed.

48 M. G. sleepers, similarly treated, were laid in the same system in December 1916. They also absorbed, on the average, about 4 lbs. per cubic foot.

In January 1925, 29 were in A class, 12 in B class, 1 in C class and 6 had been rejected after 8 years' service.

Mechanically, the timber, like *sain Terminalia tomentosa* may be expected to have a life of about 15-18 years since it is much stronger than deodar which lasts for about 14 years.

PRESENT EXPERIMENTS.

Treatment was commenced on 1st July 1924. Detailed analyses of the Creosote and Earth Oil used, are appended herewith (See Appendices A and B).

A summary of the salient features of the experiments and the details of individual experiments are also appended herewith (Appendix VI).

Experiment I. Sleepers $\frac{\text{T. M.}}{\text{9—1 to 23}}$ were treated with a mixture of 25 per cent. Creosote and 75 per cent. Earth Oil by the Lowry Process.

The average moisture content was 13·9 per cent., and the corresponding Specific Gravity of the wood was ·70. The moisture content varied, in individual cases, between 10 per cent. and 30·1 per cent. A pressure of 175 lbs. per sq. inch was developed in 35 minutes until the gross absorption was 8·6 lbs. per cubic foot on the average.

A vacuum of 16 inches was afterwards maintained in the cylinder for half an hour. The average nett absorption was 8·0 lbs. per cubic foot with variations in individual cases, from 6·0 lbs. to 10 lbs. per cubic foot, the absorptions being fairly uniform.

Sleeper No. 1, with moisture content of 15·8 per cent., and with an absorption of 6·7 lbs. per cubic foot on being cut at the rail seat, was found to have oil throughout the timber. The penetration was very thorough and satisfactory, and resembles that obtained with *sain*.

Sleeper No. 12, with an average moisture content of 30·1 per cent., was cut at the rail seat, and the end portion split to examine the penetration which extended to 1″ or 2″ all round and 7″ to 8″ from the end. This sleeper had retained 8·0 lbs. per c. ft.

Experiment II.— Sleepers $\frac{\text{T. M.}}{\text{9—24 to 46}}$.

The same oil as in Experiment I was used, the Lowry process being adhered to.

The average Specific Gravity of the wood was ·66, corresponding to an average moisture content of 15·5 per cent. ; the moisture content varied from 6 per cent. to 34·9 per cent.

A pressure of 175 lbs. per sq. inch was developed in 55 minutes, the final vacuum being 15 inches for 20 minutes. The average gross absorption was 8·6 lbs. per cubic foot.

The average nett absorption was 7·7 lbs. per cubic foot, with variations from 6 lbs. to 10·6 lbs. per cubic foot.

Sleeper No. 24, with moisture content 16 per cent. was cut at the rail seat and was found to be completely impregnated. This sleeper had retained 7·6 lbs. per cubic foot. Sleeper No. 37, with moisture content of 10·8 per cent. had absorbed 8 lbs. per cubic foot and on being cut open, was found to have oil throughout.

Experiment III.—Sleepers $\frac{\text{T. M.}}{9-47 \text{ to } 69}$.

The antiseptic used was a mixture of equal parts of Creosote and Earth Oil, the Lowry process being used.

The average Specific Gravity of the wood, corresponding to an average moisture content of 15·7 per cent. was ·64 ; the moisture content varied between 10·8 per cent. and 27·4 per cent.

A pressure of 175 lbs. per sq. inch was developed in 15 minutes, and maintained for a further 40 minutes. This was followed by a vacuum of 15 inches, for 25 minutes, so that the gross absorption of 12 lbs. per cubic foot was reduced to an average nett absorption of 8·8 lbs. per cubic foot varying in individual cases, from 6·7 lbs. to 10·7 lbs. per cubic foot, very uniform absorptions being obtained.

No cutting was reckoned to be necessary as the wood, with even 6·7 lbs. per cubic foot, can be completely impregnated ; in the present experiment, the least absorption was 6·7 lbs. per cubic foot.

Experiment IV.—Sleepers $\frac{\text{T. M.}}{9-70 \text{ to } 92}$.

The same oil and process, used in Experiment III, were adhered to.

The average Specific Gravity of the wood was ·64, corresponding to an average moisture content of 21·2 per cent.; the moisture content varied, in individual sleepers, between 11·5 per cent. and 49·5 per cent.

A pressure of 175 lbs. per sq. inch was developed in about 15 minutes and maintained for a further 45 minutes. A final vacuum of 16 inches was applied for 20 minutes, the average nett absorption being 8·1 lbs. per cubic foot with variations from 6·0 lbs. to 10·3 lbs. per cubic foot, in individual cases.

Sleeper No. 88, with an absorption of 7·3 lbs. per cubic foot, was cut open and was found to be thoroughly impregnated.

Experiment V.—Sleepers $\frac{\text{T. M.}}{9-93 \text{ to } 115}$.

The oil used was a mixture of 1 part of Creosote and 2 parts of Earth Oil ; the treatment was by the Lowry process.

The average Specific Gravity of the wood was ·70 corresponding to an average moisture content (which varied from 8·2 per cent. to 28 per cent.) of 16·5 per cent.

A maximum pressure of 175 lbs. per sq. inch was developed in about 30 minutes, and maintained for a further 30 minutes, followed by a vacuum of 17 inches for 20 minutes.

The average gross absorption was 9·1 lbs. per cubic foot, the average nett absorption being 6·5 lbs. per cubic foot, with variations between 5·0 lbs. and 9·7 lbs. per cubic foot in individual sleepers. The absorptions were very uniform.

Sleeper No. 107, with moisture content of 19·7 per cent. had retained only 5·0 lbs. per cubic foot, and on cutting, was found to be completely penetrated. This being the sleeper with the lowest absorption for the charge, it is safe to conclude that the others had received a thorough impregnation of the oil.

Experiment VI.—Sleepers $\frac{\text{T. M.}}{9\text{—}116 \text{ to } 137}$.

The oil and process of treatment employed in the experiment were the same as those in Experiment V.

The average Specific Gravity of the wood was ·71 corresponding to an average moisture content (which varied in individual sleepers from 10·7 per cent. to 24·6 per cent.) of 16·4 per cent.

A pressure of 175 lbs. per sq. inch was developed in one hour, a gross absorption of 7·8 lbs. per cubic foot being obtained.

A vacuum of 17 inches was applied for 25 minutes, reducing the average nett absorption to 7·3 lbs. per cubic foot, with variations in individual sleepers, between 6·0 lbs. and 8·7 lbs. per cubic foot.

Sleeper No. 121, with an absorption of 6·7 lbs. per cubic foot, and a moisture content of 17·6 per cent., was cut open below the rail seat and was found to be completely impregnated with the oil.

Experiment VII.—Sleepers $\frac{\text{T. M.}}{9\text{—}139 \text{ to } 140}$ and ten Timber Testing Section sleepers of the same species.

Pure Creosote was used, the treatment being by the Lowry process. The average Specific Gravity of the wood was ·73 corresponding to an average moisture content of 20·3 per cent. which varied, in individual sleepers, between 15 per cent. and 27·8 per cent.

A pressure of 175 lbs. per sq. inch was developed in 15 minutes, and maintained for a further 45 minutes, a gross absorption of nearly 10 lbs. per cubic foot being obtained.

A final vacuum of 15 inches for 25 minutes, reduced the nett absorption to 9·3 lbs. per cubic foot with variations in individual cases from 5·3 lbs. to 11·0 lbs. per cubic foot.

Creosote appeared to be a better penetrant than its mixtures with Earth Oil.

Sleeper No. 140 was cut at the rail seat; the moisture content was 12·9 per cent. and the absorption 11·0 lbs. per cubic foot. The sleeper was completely impregnated with oil.

Experiment VIII.— $\frac{\text{T. M.}}{9\text{—}141 \text{ to } 162}$.

In this last experiment of the consignment, treatment was by the Lowry process with pure Creosote.

The average specific gravity of the wood was ·69 corresponding to an average moisture content (which varied in individual sleepers between 10·1 per cent. and 25·7 per cent.) of 16·4 per cent.

A pressure of 175 lbs. per sq. inch was developed gradually, in about 40 minutes, and maintained for a further 20 minutes, a gross absorption of 9 lbs. per cubic foot being obtained.

A final vacuum of 16 inches for 25 minutes reduced the nett absorption to 8·6 lbs. per cubic foot, with variations in individual cases from 5·7 lbs. to 11·0 lbs. per cubic foot. The absorptions were fairly uniform.

Sleeper No. 160, with an absorption of 5·7 lbs. per cubic foot, was cut open under the rail seat and was found to have oil throughout. The moisture content of the sleeper was 24·1 per cent.

CONCLUSIONS AND RECOMMENDATIONS.

From the above experiments, it is clear that *Terminalia myriocarpa* (*hollock*) is amenable to pressure treatment with Creosote or its mixtures with Earth Oil. The wood appears to take even as much as 12 lbs. per cubic foot. The optimum economic absorption, from the observations made, appears to be about 7 lbs. per cubic foot (nett absorption), a complete impregnation being ensured.

In the 172 sleepers treated, the minimum absorption obtained was 5·3 lbs. per cubic foot, the charging temperature being between 180° and 200°F, and the pressure period being about an hour.

In a commercial plant, working a 10 hour-day, four charges of this wood can be treated per day.

Fluctuations in moisture content below the 'fibre saturation point' (about 28 per cent.) appear to have no corresponding effect on the respective absorptions.

When Creosote alone was used, as in the case of the other Assam hardwoods, working according to the same schedule of operations, heavier absorption was obtained than with the Creosote and Earth Oil mixtures It appears that Creosote is a better penetrant than the other mixtures; for what reasons, it is difficult to discern at present.

It was observed that the bulk of the absorption occurred within the first 30 minutes, *i.e.*, in the earlier stages of the pressure period. It is desirable to make this period as long as is consistent with economical considerations for two reasons, (1) so as to keep the timber under the sterilizing influence of heat for as long as possible (2) to even up the distribution of oil throughout the wood.

The suggested specification for this wood would therefore be :—

Modified Lowry process using a slowly built up pressure attaining a maximum of 175 lbs. per sq. inch in about 30 minutes, and held for about 30 minutes or until an average gross absorption of 10 lbs. per cubic foot has been obtained.

A vacuum of 20 inches to 24 inches for about 30 minutes so as to reduce the absorption to an average of 7 lbs. per cubic foot. The charging temperature of the oil should be about 200°F. and the retort temperature about 180°F.

The wood absorbs 1½ lb. to 2 lbs. per cubic foot as the oil enters the cylinder, depending on the time taken to fill the cylinder.

NOTE VII.—Note on treatment of *Lagerstroemia Flos-Reginæ* (*ajhar*).

200 Metre Gauge sleepers from the Sibsagar district of Assam were received at Dehra Dun on the 2nd January 1924. On arrival they were quite green having a moisture content of 117 per cent. on the average. They were stored in a well ventilated godown for purposes of seasoning and observation.

Twenty matched sleepers were handed over to the Timber Testing Section for purposes of strength and spike holding tests; 21 were rejected onaccount of bad cracks. The remainder were marked according to the scheme laid down in Project IV namely $\frac{\text{L. F. R.}}{32-1 \text{ to } 159}$.

Ten sleepers were chosen for seasoning observations and when examined on the 5th of April showed an average moisture content of 79·5 per cent. On the 7th May they were again examined and showed a moisture content of 59·5 per cent.; on the 3rd June this had been reduced to 43·4 per cent. They were all removed to the Tiemann kiln on 8th of July and taken out on the 9th of August when the moisture content was reduced to 34·2 per cent.

The Forest Economist examined them later during treatment and reported as follows on their condition.

"A good lot of sleepers, with few cracks and no twist. The only defects are in a few sleepers with boxed heart where splitting is somewhat serious The defects caused by boxing the heart are not sufficiently serious to necessitate special provisions against including the heart."

From the above observations it will be apparent that the sleepers are slow in seasoning but that when properly protected from the sun do not show any serious degrade when seasoned in 9 months.

LIFE UNTREATED.

Records show that this timber, although not reckoned as durable for sleeper work, is very fair in this respect, a life of seven years, untreated, being the average. Of 100 metre gauge sleepers laid near Moriani on the Assam Bengal Railway in March 1918, 92 per cent. were sound in all respects in October 1922 and only 2 per cent. had been rejected.

In January 1925, they were deteriorating fast, 50 per cent. only being good.

PREVIOUS RECORDS OF TREATMENT.

As far as can be ascertained this wood has not previously been experimented with, hence there are no records of its treated life.

A sample of the timber was sent to England in 1922 by the South Indian Railway group and treated by Messrs. Burt Boulton and Haywood Ltd., at Silvertown.

The results obtained were at variance with those obtained in the present experiments which may be explained on the grounds of abnormality or that the wrong timber was sent the latter being the more probable explanation.

PRESENT EXPERIMENTS.

Experiment I.—Sleepers No. $\frac{\text{L.F.R.}}{\text{32—1 to 23}}$.

The charge was treated by the Lowry Process with a mixture of 50 per cent. Creosote and 50 per cent. Earth Oil. The maximum pressure applied was 175 lbs. per sq. inch which was attained in 35 minutes and maintained for a further 2 hours and 15 minutes making a total period of 2 hours and 50 minutes.

This was followed by a vacuum of 16 inches for 25 minutes. The average moisture content at time of treatment was 18·3 per cent. with individual variations from 12 per cent. to 30 per cent. The average specific gravity of the charge was ·64. The average gross absorption was 1·7 lbs. per cubic foot which was reduced by the vacuum to an average nett absorption of ·84 lbs. of oil per cubic foot. This absorption varied from almost nothing to 2·7 lbs. per cubic foot.

Sleeper number 12 with a moisture content of 21 per cent., absorbed 1 lb. of oil per cubic foot. On splitting, it was seen that the surface only had been treated and that the oil had penetrated about 1 inch along the end.

Sleeper No. 22 with a moisture content of 14·5 per cent., showed a side penetration of about ⅛ inch and an end penetration of 1 inch due to an absorption of 2·7 lbs. per cubic foot.

That the extra absorption is not due to the low moisture content is shown by fact that sleeper number 23 with a moisture content of 13·4 per cent., absorbed practically nothing.

During the first few minutes of the pressure period the pressure rose to 50 lbs. per sq. inch and after 35 minutes had reached 175 lbs. per sq. inch. The absorption was approximately 20 lbs. for the charge of 34 cubic foot or 0·6 lbs. per cubic foot. A similar quantity was pressed in, in a further 10 minutes with the pressure maintained at 175 lbs. Only a slight increase was obtained in the next twenty minutes and during the last half hour practically nothing.

Experiment II.—Sleepers No. $\frac{\text{L.F.R.}}{\text{32—25 to 47}}$.

The charge was treated with a mixture of 50 per cent. Creosote and 50 per cent. Earth Oil by boiling the timber in the oil under a vacuum of 15 inches for 24 hours at 190°F.

Pressure up to a maximum of 175 lbs. per sq. inch was then applied for one hour followed by a vacuum of 15 inches for 20 minutes.

The average moisture content of the charge was 20·3 per cent. with variations from 15·2 per cent. to 30·2 per cent. The average specific gravity of the charge was ·61.

The nett average absorption per cubic foot was only ·75 lbs. which varied from very little to 2·3 lbs. per cubic foot. Sleeper No. 47 with a moisture content of 20·8 per cent. absorbed 1 lb. of oil per cubic foot. On cutting the sleeper it was seen that the sapwood (at one corner) was completely penetrated but that the remainder had a surface treatment only. The end penetration was only 1 inch.

During the first 10 minutes of the pressure period the absorption with 150 lbs. pressure was a little over 1 lb. per cubic foot. on the average, which was only slightly increased in the remaining 50 minutes, the pressure meanwhile rising to 175 lbs. This gross quantity was subsequently reduced by the vacuum.

Experiment III.—Sleepers No. $\frac{\text{L. F. R.}}{\text{32—48 to 66}}$.

These sleepers were treated by boiling in a mixture of 50 per cent. Creosote and 50 per cent. Earth Oil for 4 hours at a temperature of 180°F. using no vacuum and no pressure period ; an open tank treatment without any cooling period. This experiment and experiment IV were carried out to sterilize the wood and give it a coat of preservative in order to gauge the value of merely cooking the wood without penetration of antiseptic.

The absorption obtained was only ·9 lbs. per cubic foot with variations from 0·3 to 1·6 lbs. per cubic foot.

The average moisture content of the charge was not determined but probably did not exceed 20 per cent.

Experiment IV.—Sleeper No. $\frac{\text{L. F. R.}}{\text{32—67 to 83}}$.

A repetition of experiment III. Average nett absorption ·72 lbs. per cubic foot.

Experiment V.—Sleepers No. $\frac{\text{L. F. R.}}{\text{32—88 to 105}}$.

The charge was treated with a mixture of 50 per cent. Creosote and 50 per cent. Earth Oil by boiling under a vacuum of 20 inches for 3 hours at a temperature of 175° F. followed by a pressure period of one hour. The average nett absorption was about 1 lb. per cubic foot with variations from ·6 lbs. per cubic foot to 1·6 lbs. per cubic foot. From pre-

vious experiments it is seen that this absorption gives very little depth of penetration.

Experiment VI.—Sleepers No. $\frac{\text{L. F. R.}}{\text{32— 06 to 1.9}}$.

This experiment was a repetition of number V with a resulting nett absorption of 1·1 lbs. per cubic foot with variations from ·6 lbs. to 2 lbs. per cubic foot.

Experiment VII.—Sleepers No. $\frac{\text{L. F. R.}}{\text{32—.30 to 151}}$.

This charge was treated with a mixture of 50 per cent. Creosote and 50 per cent. Earth Oil, by the Full Cell Process.

A preliminary vacuum of 22 inches was applied for 45 minutes followed by a pressure period of three hours, the maximum pressure being 175 lbs. per sq. inch. A final vacuum of 20 inches for 15 minutes was applied to remove oil from the surface of the wood. The average moisture content of the charge was 18·6 per cent. with variations from 11·9 per cent. to 27·4 per cent.

The average nett absorption was 1·6 lbs. per cubic foot varying from 2·4 to 0·6 lbs. of oil per cubic foot in individual cases. The low absorption indicates that a very small penetration was obtained except in the sappy portions which, from previous observations, are known to be completely impregnated.

As previously observed, practically the whole of the absorption took place in the first half hour of the pressure period, the final hour being responsible for very little.

Experiment VIII.—Sleepers No. $\frac{\text{L. F. R.}}{\text{32—152 to 159}}$.

These sleepers were treated with ten specimens of *Vateria indica* belonging to the Timber Testing Section. They were treated with pure Creosote.

Vateria indica was known to be a difficult wood to treat so that there was no danger of one species robbing the other of oil.

A vacuum of 26 inches was applied to the charge for 45 minutes followed by a pressure of 175 lbs. per sq. inch maximum for 2 hours and 15 minutes. A final vacuum of 20 inches was drawn for 20 minutes.

A nett average absorption of 1·5 lbs. per cubic foot was obtained for *Lagerstrœmia Flos Reginæ* which varied from ·66 to 2·6 in individual cases.

The average moisture content was 16·1 per cent. varying from 6·6 per cent. to 22·7 per cent.

Conclusions.

From the above experiments it is obvious that it is exceedingly difficult to obtain an absorption of over 2 lbs. per cubic foot with this species

no matter what process is employed. The depth of penetration with such an absorption is practically nothing except in sappy portions of the timber. The timber however is a very good one and does not fall very far short of the durability mark (reckoned as ten years life) when untreated. It is therefore quite probable that the light treatment will turn the scale and give an increase in life more than commensurate with the cost of treatment.

The antiseptic must be given every chance however and for this reason it is strongly recommended that a pressure period of at least 3 hours be employed so as to sterilize the wood. This means that only two charges per day can be expected so that labour charges will amount to about 10 annas per sleeper. The oil cost however using a mixture of 50 per cent. Creosote and 50 per cent. Earth Oil will not be more than 3 annas per sleeper making a total of 13 annas.

Provided therefore the treatment is capable of giving protection for 12 years (a period by no means unlikely in view of past experience) the use of *Lagerstrœmia Flos-Reginœ* as a railway sleeper is by no means an unattractive proposition. Even if pure Creosote be used as the antiseptic, the total cost of treatment would not be more than Re. 0-14-6.

The timber however must be well seasoned so as to avoid subsequent splitting in service.

The following specification is therefore advised :—

Antiseptic—Pure Creosote.
Preliminary vacuum, 24 inches for ¾ hours.
Pressure raised slowly to 175 lbs. per sq. inch during 3 hours.
Charging temperature of oil, 180° to 190°F
Maximum Retort Temperature, 175° to 180°F.
Final vacuum, sufficient to prevent dripping.

APPENDIX I.

Name of timber	No	Process used	Oil used	Per cent moisture content at time of treatment	S. G. of air dried wood	Vacuum applied before treatment and time.	Maximum pressure applied and duration	Vacuum applied after treatment and time	Temperature range during treatment	Gross absorption lbs per c. ft	Nett absorption lbs per c. ft	Penetration as determined by boring or splitting	Remarks and how disposed of.
Experiment I.													
Cynometra polyandra	1	Full Cell	Creosote 50 per cent Earth Oil 50 per cent	24·7	94	16 inches for 30 minutes	175 lbs. per square inch for 1 hour	13 inches for 20 minutes	180°F to 200° F	7·7 lbs	5·6	Complete	
	2			41·2							8·0		
	3			27·6							2·6		
	4			20·4							8·6		
	5			40·5							9·0		
	6			26·9							5·0		
	7			21·9							3·6		
	8			31·2							2·6		
	9			15·9							5·0		
	10			22·4							8·3		
	11										2·3		
	12										4·6		
	13										5·6		
	14										4·0		
	15										8·0		
	16										4·0		
	17										7·6		
	18										5·3		
	19										8·6		
	20										11·3		
	21										7·6		
	22										8·6		
AVERAGE				26·64							5·95		
Experiment II.													
	23		per cent	22							6·6		
	24			18							7·6		
	26			19							6·6		
	27			41							4·0		
	28			21							5·0		
	29			18							6·6		

Cynometra polyandra.	30	Lowry.	Creosote 50 per cent. Earth Oil 50	21	·95	Nil.	175 lbs. per square inch for 1½ hours.	18 inches for 40 minutes.	180°F to 185°F.	6·7 average.	8·3	Satisfactory ¼ inch all round.
	31			21							7·0	
	32			57							6·8	
	33			37							4·6	
	34			49							4·6	
	35			21							5·0	
	36			21							6·3	
	37			21							3·0	
	38			28							8·0	
	39			33							2·0	
	40			20							3·3	
	41			22							4·0	Sapwood entirely penetrated ¼ inch impregnation all round.
	42			17							6·0	
	43			27							7·3	
	44			17							7·6	
	45			27							2·6	
	46			48							3·6	
	47			23							8·3	
AVERAGE	..	..	..	27·04	.	..	..	..	..	..	5·6	

Experiment III.

Cynometra polyandra.	48	Full Cell.	Creosote 37 per cent. Earth Oil 63 per cent.	24·7	·92	15 inches for 45 minutes.	175 lbs per square inch for 1 hour.	15 inches for 10 minutes.	185°F. to 190°F.	Since 9 sal posts were treated along with the sleepers the gross absorption per cubic feet for this wood is not known.	5·3	
	49			22·9							8·3	
	50			23 5							6·3	
	51			23·0							4·3	
	52			50·6							7·6	Sapwood almost complete. Heart surface little. About 80 per cent. sapwood.
	53			33·3							6·3	
	54			26·1							8·3	
	55			43·5							4 0	
	56			27 2							5·3	
	57			24 7							3·0	Sapwood complete. Heart surface little. Some oil in heart.
	58			19 9							5·3	
	59			21·1							4·3	
	60			26·5							4·0	
	61			33 2							4 3	
	62			34·5							4·0	
	63			38·2							5·6	
	64			21·5							5·0	
	65			21·7							5·3	
	66			25·5							5·3	Completely saturated.
	67			23·6							9·6	
AVERAGE	..	..	..	28·3	..	..	..	..	..	.	5·57	

APPENDIX I—*contd.*

Experiment IV.

Name of timber.	No.	Process used	Oil used.	Per cent moisture content at time of treatment.	Sp. Gr. of air dried wood	Vacuum applied before treatment and time.	Maximum pressure applied and duration	Vacuum applied after treatment and time	Temperature range during treatment	Gross absorption lbs per c. ft	Nett absorption lbs per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Cynometra polyandra.	68	Full Cell	Creosote 37 per cent. Earth Oil 63 per cent.	31·1	·97	17 inches for 40 minutes	175 lbs per square inch for 2 hours 15 minutes	15 inches for 10 minutes.	180°F. to 195°F	6 2 average.	5·0		
	69			31 5							8·6		
	70			44 6							3·3		
	71			18·1							5·6		
	72			23·6							2·3	Sap complete. Heart nil to ¼ inch.	
	73			21·6							7·0		
	74			38 8							3·6		
	75			21·5							8·0		
	76			23·0							5·3		
	77			24·6							8·6		
	78			16·2							10·0		
	79			20 7							4·0		
	80			34·5							7 3		
	81			30·4							10·0		
	82			23·8							4·3		
	83			26 9							4·6		
	84			38 6							4·0		
	85			38 3							3·3		
	86			21·0							8·6		
	87			27·6							7·3		
	88			29 1							8·6		
	89			35·1							3·0		
	90			36·6							6·3	80 per cent. cross section complete. Sap saturated.	
	91			24·6							8·6		
AVERAGE	..	..	..	28·5	..	..	..	..	..	..	6·1		

Experiment V.

Cynometra polyandra.	93	Full Cell.	Creosote.	14·3	·91	17 inches for 40 minutes.	175 lbs per square inch for 1 hour.	13 inches for 20 minutes.	165°F to 105°F.	This experiment was carried out with a composite charge of *Cynometra polyandra* and *Dichopsis elliptica* so that the gross absorption by *Cynometra polyandra* was not known.	13·7	Sap satisfactory. Heart erratic.	
	94			30·7							8·3		
	95			22·1							9·0		
	96			30·6							6·0		
	97			40·0							7·0		
	98			24·7							10·3		
	99			40·3							3·7		
	100			..							8·7		
	101			19·7							7·3		
	102			16·4							8·7		
	103			18·6							7·3		
	104			22·3							7·3		
	105			.							9·7		
	106			19·3							9·0		
	107			32·3							6·0		
	108			16·5							12·0		
	109			35·3							10·7		
	110			18·2							12·0		
	111			18·9							8·7		
AVERAGE .	..	..	.	24·7	..	.	..	..	..	..	8·7		

Experiment VI.

Cynometra polyandra	112	Full Cell.	Creosote.	26·7	·92	17 inches for 40 minutes.	100 lbs. per square inch for 30 minutes followed by 175 lbs. per square inch for 20 minutes.	13 inches for 15 minutes	135°F to 150°F.		3·0	Nil on heart to 1 inch on sap surface.	
	113			16·8							7·6		
	114			15·4							11·0		
	115			26·3							10·6		
	116			24·5							6·0		
	117			11·2							7·6	Complete.	
	118			23·7							4·3		
	119			13·6							12·3		
	120			21·9							6·0		
	121			16·9							6·3		
	122			37·5							4·6		
	123			90·0							12·3		
	124			21·4							6·6		
	25			31·2							2·6		
	1			19·0							6·6	..	Sent to T. T. Section for strength test after treatment.
	2			18·0							12·6		
	3			22·4							7·0		
	4			18·9							10·0		
	5			19·8							11·0		
	6			18·6							10.8		
	7			17·1							3·6		
	8			22·7							5·3		
	9			26·8							3·3		
	10			31·3							10·6		
AVERAGE .	..	..	..	24·7	..	..	:	..	..	..	7·6		

APPENDIX I—*concld.*

Experiment VII.

Name of timber	No	Process used	Oil used	Per cent moisture content at time of treatment.	S G of air dried wood	Vacuum applied before treatment and time	Maximum pressure applied and duration	Vacuum applied after treatment and time	Temperature range during treatment	Gross absorption lbs. per c ft.	Nett absorption lbs. per c ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Cynometra polyandra	125	Full Cell.	Creosote :0 per cent. Earth Oil 70 per cent.	17 6	·90	15 inches for 40 minutes	175 lbs. per square inch for 10 minutes.	14 inches for 15 minutes.	160°F to 180°F.	7 lbs. average.	6 3	Oil completely penetrates 70 per cent. of cross section; Surface treatment on heart to 2 inches on sap surface.	
	126			25·0							4·3		
	127			21·3							7·6		
	128			20 4							5·6		
	129			15 5							7·0		
	130			28 1							2 8		
	131			22 3							7·3		
	132			20 3							4·3		
	133			21 8							5·6		
	134			45 2							3·3		
	135			19·2							4·0		
	136			25·9							7·6		
	137			40 4							4·0		
	138			17·5							4·3		
	139			16·3							9·6		
	140			15·5							3·6		
	141			33·6							4·3		
	142			22·4							3·3		
	143			22·3							6·6		
	144			35·1							4·0		
	145			18·7							3·6		
	146			18·9							8·0		
	147			29·4							6·3		
	148			20·9							6·0		
AVERAGE	..	..		23·9	..	.	.	..	..	..	5·4		

Experiment VIII.

Cynometra polyandra	149	Full Cell	Creosote 25 per cent Earth Oil 75 per cent	20 2	96	17 inches for 40 minutes	175 lbs per square inch for 1 hour	14 inches for 20 minutes	170°F. to 185°F	57	3 3	Sap complete, heart ¼ inch
	150			25 9							7 3	
	151			14 9							5·0	
	152			16 6							1 6	
	153			25·0							6·3	
	154			19 2							6·0	
	155			21 1							3 3	
	156			12 8							3 0	
	157			29 3							11 6	
	158			31 2							3 3	
	159			19 3							2 3	
	160			18 6							2·0	
	161			15 1							4 3	
	162			13 1							7·0	Satisfactory, 60 per cent. sap complete. Heart erratic
	163			19 9							5 3	
	164			18 2							2 6	
	165			25 9							4 6	
	166			22 9							4 3	
	167			14 1							5 3	
	168			35 4							4 0	
	169			22 6							7 3	
	170			18 9							5 3	
	171			20·4							10 3	
	172			13 8							7·6	
AVERAGE				20 6							5 1	

APPENDIX II.

Experiment I.

Name of timber.	No.	Process used.	Oil used.	Per cent. moisture content at time of treatment.	S. G. of air dried wood.	Vacuum applied before treatment and time.	Maximum pressure applied and duration.	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lbs. per c. ft.	Nett absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Dipterocarpus pilosus.	1	Lowry.	Creosote 50 per cent. Earth Oil 50 per cent.	14·14	·81	Nil	160 lbs. per square inch for ½ hour.	16 inches for ½ hour.	210°F.	8·3	5·6	Resinous on ends. Creosote throughout. Ditto under rail seat. End complete.	
	2			30·16							6·3		
	3			60·51							4·3		
	4			37·95							4·6		
	5			59·66							6·3		
	6			52·65							6·6		
	7			51·58							5·6		
	8			42·63							5·0		
	9			41·96							8·6		
	10			51·28							4·3		
	11			22·33							5·3		
	12			47·33							4·3		
	13			64·74							4·6		
	14			33·88							2·6	Not resinous on ends. Sapwood complete and heart mottled throughout. Under rail seat almost complete.	
	15			34·01							8·0		
	16			41·66							6·6		
	17			37·69							5·3		
	18			41·05							4·6		
	19			43·29							6·3		
	20			59·23							3·3		
AVERAGE	..	..	..	43·39	..	..	..	..	..	..	5·4		

Experiment II.

Dip treatment pieces.	21	Lowry.	Creosote 50 per cent. Earth Oil 50 per cent.	55·2	·8	Nil.	180 lbs per square inch for ½ hour.	16 inches for ¾ hour.	210°F.	7·0	4·3	Penetration is in patches throughout the wood.
	22			37·5							4·6	
	23			111·3							3·6	
	24			41·1							4·6	
	25			28·7							6·0	
	26			51·2							3·6	
	27			35·7							4·6	
	28			57·3							4·3	
	29			39·1							5·3	
	30			15·7							4·6	
	31			26·5							5·3	
	32			30·8							4·3	
	33			32·0							4·0	
	34			64·7							4·0	
	35			33·5							4·6	
	36			31·5							6·0	
	37			22·0							5·3	
	38			44·6							6·6	The same as above.
	39			27·1							7·6	
	40			25·2							5·0	
AVERAGE .	..	..	.	40·49	..	..	..	..	..	..	4·9	

Experiment III.

Dip treatment pieces.	41	Lowry.	Creosote 50 per cent. Earth Oil 50 per cent.	.	[illegible]	[illegible]	175 lbs per square inch for 1 hour.	17 inches for ¾ hour.	210°F.	8·6	4·6	Rather sappy: oil throughout.
	42			.							10·6	
	43			.							4·3	Oil in patches throughout.
	44			..							4·6	
	45			..							5·0	
	46			..							6·0	
	47			..							6·0	
	48			..							5·6	
	49			..							5·0	
	50			.							7·0	
	51			.							4·8	
	52			..							4·6	
	53			..							5·0	
	54			.							5·6	
	55			..							7·0	
	56			.							4·3	
	57			..							7·6	
	58			..							6·3	
	59			..							8·6	
	60			.							6·0	
AVERAGE .	..	..	..	..	.	..	..	..	..	..	5·9	

APPENDIX II—*contd.*

Name of timber	No	Process used	Oil used	Per cent moisture content at time of treatment	S. G. of air dried wood	Vacuum applied before treatment and time	Maximum pressure applied and duration	Vacuum applied after treatment and time	Temperature range during treatment	Gross absorption lbs per c ft	Nett absorption lbs per c ft	Penetration as determined by boring or splitting	Remarks and how disposed of.
						Experiment IV.							
Dipterocarpus pilosus.	61	Lowry	25 per cent. Creosote 75 per cent Earth Oil	40.[illegible]	80	12 inches for 15 minutes	175 lbs per square inch for 20 minutes	6 inches for 20 minutes	160° to 190°F	8.5	5.6	Sleepers over 5 lbs. per cubic foot satisfactory penetration.	
	63			1.7							[illegible]0		
	64			45.5							5.3		
	65			36.9							8.6		
	66			38.7							6.3		
	67			27.8							7.3		
	68			42.3							6.3		
	69			39.7							6.0		
	70			42.8							4.6		
	71			47.9							8.0		
	72			48.3							8.[illegible]		
	73			48.1							6.0		
	74			50.9							5.[illegible]		
	75			63.3							8.0		
	76			48.7							4.6		
	77			20.8							7.0		
	78			42.3							4.5		
	79			37.6							5.6		
	80			4[illegible].5							[illegible]0		
	81			35.8							5.[illegible]		
	82			45.0							4.3		
	83			61.5							7.0		
	84			54.6							6.5		
	85			59.3							7.3		
AVERAGE				42.55							6.2		
						Experiment V.							
	86			39.5							6.0	Sleepers with an absorption of over	
	87			52.3							5.3		
	88			44.4							7.3		
	89			24.3							5.6		
	90			28.5							7.3		

Dipterocarpus pilosus.	91	Lowry.	Creosote 25 per cent. Earth Oil 75 per cent.	36·8	·82	12 inches for 17 minutes.	: lbs. per square inch for 1 hour.	16 inches for 40 minutes.	175° to 195°F.	7·3 lbs.	5·6	5 lbs. per cubic foot complete penetration.
	92			21·5							6·0	
	93			42·3							5·3	
	94			35·1							6·0	
	95			43·0							3·0	
	96			24·8							9·0	
	97			20·9							7·6	
	98			22·7							8·6	
	99			27·7							5·3	
	100			48·8							7·0	
	101			55·5							4·6	
	102			45·6							4·3	
	103			38·9							5·3	
	104			51·4							4·6	
	105			30·5							5·6	
	106			41·0							5·3	
	107			..							3·3	
	108			37·1							3·6	
	109			42·9							6·0	
AVERAGE	..	..	..	37·6	..	..	..	..	..	..	5·8	

Experiment VI.

Dipterocarpus pilosus.	110	Lowry.	Creosote 33 per cent. Earth Oil 67 per cent.	23·2	80	15 inches for 15 minutes.	175 lbs. per square inch for 1 hour.	15 inches for 20 minutes.	170° to 175°F.	9·0 lbs.	3·6	With absorption of over 5 lbs. per cubic foot complete impregnation.
	111			30·0							5·6	
	112			31·4							7·3	
	113			36·7							8·6	
	114			26·5							6·3	
	115			15·7							11·0	
	116			48·4							6·3	
	117			29·2							6·3	
	118			35·1							9·0	
	119			30·8							4·3	
	120			28·7							6·6	
	121			38·8							7·6	
	122			39·4							6·6	
	123			36·6							5·3	
	124			14·0							6·0	
	125			30·8							6·0	
	126			34·2							11·[illegible]	
	127			41·8							7·0	
	128			14·5							7·3	
	129			38·5							6·8	
	130			29·8							6·0	
	132			18·4							6·3	
	133			38·9							6·3	
	134			42·2							4·6	
AVERAGE	..	..	..	30·9	..	..	..	..	..	..	6·9	

APPENDIX II—*concld.*

Experiment VII.

Name of timber.	No.	Process used.	Oil used.	Per cent moisture content at time of treatment.	S. G. of air dried wood.	Vacuum applied before treatment and time.	Maximum pressure applied and duration.	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lbs. per c. ft.	Nett absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Dip terocarpus pilosus.	135	Full Cell.	Pure Creosote.	29·9	·78	16 inches for 40 minutes.	175 lbs. for per square inch 1 hour.	14 inches for 20 minutes.	175° to 205·° F.	12 lbs.	8·0	Complete penetration.	
	136			21·5							10·3		
	137			26·4							8·0		
	138			25·0							10·0		
	139			22·4							14·6		
	140			43·3							7·3		
	141			15·1							12·6		
	142			29·1							13·6		
	143			38·1							8·0		
	144			43·4							8·6		
	145			25·7							9·0		
	146			26·5							19·3		
	147			46·8							7·6		
	148			49·0							7·6		
	149			24·4							10·6		
	150			23·5							14·6		
	151			15·1							5·0		
	152			27·1							6·3		
	153			16·8							12·6		
	154			34·5							12·3		
	156			27·8							12·0		
	157			25·4							7·0		
	158			20·6							9·3		
AVERAGE	..	..	..	28·6	..	..	..	..	..	..	10·2		

Experiment VIII.

	D. P.											
Dipterocarpus pilosus (12 M. G.) and *Shorea assamica* (10 M. G.)	1	Full Cell.	Creosote.	42·9	Average 0·71	16 inches for 40 minutes	175 lbs. per square inch for 1 hour	14 inches for 20 minutes	155° to 165°F	Average 10·6.	9·3	To the T. T. Section except two D. P. sleepers to be sent to A. B. Ry. track.
	2			15·8							12·3	
	3			23·2							9·0	
	4			40·2							10·3	
	5			28·8							10·3	
	6			17·2							8·6	
	7			42·7							11·6	
	8			28·7							10·3	
	9			32·1							11·3	
	10			35·9							11·6	
	155			37·2							17·6	
	159			21·1							11·0	
	S. A. 1			19·1							16·0	
	2			27·4							6·6	
	3			28·2							7·6	
	4			25·8							5·3	
	5			25·3							4·0	
	6			27·3							9·6	
	7			25·2							4·6	
	8			30·0							4·0	
	9			24·4							5·0	
	10			28·3							6·6	
											..	
Average .	.	..		28·5	.		.	..	.	.		
Average for D. P.	..	..		.	..	..	.	..		.	11·1	
Average for S. A.	.	..		..		.	.	..		..	6·9	

APPENDIX III.

Experiment I.

Name of timber.	No.	Process used.	Oil used	Per cent. moisture content at time of treatment.	S. G. of air-dried wood.	Vacuum applied before treatment and time.	Maximum pressure applied and duration.	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lbs. per c. ft.	Netz absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Shorea assamica.	1	Lowry.	Creosote 50 per cent. Earth O.l 50 per cent.	30·5	·69	*Nil.*	175 lbs. per square inch for 2½ hours.	20 inches for ¼ hour.	200°F.	5 lbs.	5·0	One sappy corner complete average ¾ inch. Under rail seat almost complete, good from spike holes. End penetration along summer wood 10".	Wood too wet, will treat better when drier.
	2			22·0							6·6		
	3			31·0							6·0		
	4			58·0							4·0		
	5			52·0							5·3		
	6			38·0							4·3		
	7			37·0							4·3		
	8			37·0							4·0	½" all round in middle, ditto under rail seat, end penetration from spike holes good along summer wood, end 10 inches.	
	9			26·0							6·6		
	10			36·0							5·0		
	11			43·0							5·3		
	12			60·0							5·6		
	13			44·0							4·6		
	14			25·0							7·0		
	15			16·0							6·3		
	16			31·0							4·6		
	17			41·0							4·6		
	18			37·0							6·3		
	19			19·0							6·3		
	20			36·0							5·3		
AVERAGE .	..	..	..	36·0	..	..	..	..	..	..	5·4		

Experiment II.

Shorea assamica.	21	Full Cell.	Creosote 50 per cent. Earth Oil 50 per cent.	26·2	·64	15 inches for 1½ hour.	175 lbs per square inch for 2½ hours.	15 inches for 20 minutes.	210°F.	6 lbs.	6·0	Side ¼ inch, end 12 inches, under rail seat mottled throughout.	Too wet for satisfactory treatment.
	22			58·3							7·8		
	23			20·0							4·0		
	24			13·6							4·6		
	25			11·9							5·0		
	26			15·3							4·6		
	27			69·7							5·3		
	28			35·3							4·3		
	29			30·4							4·3		
	30			17·8							4·6		
	31			32·4							4·3		
	32			22·8							4·0		
	33			28·4							4·0		
	34			15·2							6·6		
	35			15·7							3·0		
	36			19·4							4·6		
	37			66·3							3·3	Surface only under rail seat good from spike holes, end 10 inches.	
	38			19·1							3·6		
	39			69·7							5·0		
	40			17·1							3·0		
AVERAGE	..	..	..	29·9	..	..	..	..	..	..	4·6		

Experiment III.

Shorea assamica.	41	Full Cell	Creosote 33 per cent Earth Oil 67 per cent.	7·8	·16	16 inches for 40 minutes.	175 lbs per square inch for 1 hour 35 minutes.	13 inches for 20 minutes	100° to 175°F.	..	12·0	
	42			18·2							5·3	
	43			22·2							7·3	
	44			32·6							5·3	
	45			33·3							6·6	
	46			31·6							4·6	
	47			11·3							8·6	
	48			28·8							7·6	
	49			31·6							5·0	
	50			27·5							7·0	
	51			50·0							8·6	
	52			33·3							5·0	
	53			23·7							4·0	Satisfactory end penetration and near the spike holes
	54			30·3							4·0	
	55			38·7							6·0	
	56			36·1							5·3	
	57			39·6							5·0	
	58			25·8							7·0	Sap, complete impregnation. surface treatment or $\frac{1}{16}$ inch to ¼ inch in sides.
	59			25·8							11·3	
	60			20·7							5·3	
	61			34·0							5·0	
	62			16·0							6·0	
AVERAGE	..	..	..	28·2	..	..	..	..	..	..	6·4	

APPENDIX III—*contd.*

Name of timber.	No.	Process used.	Oil used.	Per cent. moisture content at time of treatment.	S. G. of air-dried wood.	Vacuum applied before treatment and time.	Maximum pressure applied and duration.	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lbs. per c. ft.	Nett absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
				Experiment IV.									
Shorea assamica.	63	Lowry.	Creosote 33 per cent. Earth Oil 67 per cent.	19·7	·67	12 inches for 15 minutes.	175 lbs. per square inch for 15 minutes.	14 inches for 20 minutes.	185° to 200°F.	6·0	7·6		
	64			42·6							4·3		
	65			21·1							5·6		
	66			25·9							5·3		
	67			41·3							5·6		
	68			35·7							6·3		
	69			25·2							3·6		
	70			25·2							5·3		
	71			38·8							8·3		
	72			26·0							5·6	Sap complete, end 6 inches, side ¼ inch to ½ inch.	
	73			19·8							7·3		
	74			19·5							7·0		
	75			40·9							4·6		
	76			29·2							5·3		
	77			17·2							7·6		
	78			21·1							5·8		
	79			22·9							4·3		
	80			43·6							4·3		
	81			15·5							9·3		
	82			28·5							4·3		
	83			19·1							4·0	Side 1/16 inch to ¼ inch end 4 to 6 inches.	
	84			11·3							5·3		
				..							..		
AVERAGE	..	..	..	26·9	..	..	..	..	..	..	5·7		
				Experiment V.									
	85			11·2			minutes.				2·6	End 4 inches, Side 1/16 to ¼ inch.	
	86			17·1							3·0		
	87			10·3							6·3		
	88			33·9							3·3		
	89			26·9							3·6		
	90			13·8							3·3		

Shorea assamica.	91	Full Cell.	Creosote (Unadulterated).	22·2	·67	15 inches for 40 minutes	160 lbs per square inch for 40	13 inches for 20 minutes.	180° to 190°F.	6·7	13·0		Average treatment. Sap complete; Heart $\frac{1}{4}$ inch to $\frac{1}{2}$ inch. Good end penetration.
	93			12·8							7·6		
	94			18·5							5·0		
	95			21·9							4·0		
	96			23·1							3·6		
	97			24·[illegible]							3·3		
	98			16·3							3·6		
	99			20·0							10·0		
	100			17·0							1·6		
	101			17·6							3·6		
	102			35·1							8·0		
	103			31·1							9·0		
	104			21·8							11·0		
	105			22·3							4·3		
	106			16·0							5·0		
	107			13·8							5·6	Sap complete. End 6 inch. Side $\frac{1}{16}$ inch to $\frac{1}{4}$ inch.	
AVERAGE	..	..	..	21·2	..	..	..	..	..	..	5·5		

Experiment VI.

Shorea assamica	108	Full Cell.	Creosote (Neat).	28·3	·67	17 inches for 10 minutes	150 lbs per square inch for 20 minutes.	13 inches for 20 minutes	175° to 185 F.	9·3	4·8		Sleepers with 6 lbs. per cu. ft. Sapwood complete penetration. Heart $\frac{1}{16}$ to $\frac{1}{4}$ inch. Sleepers with 3 lbs. per cu. ft. surface treatment only.
	109			45·5							4·6		
	110			23·2							4·6		
	111			33·7							[illegible] 3		
	112			33·2							6·6		
	113			32·3							5·0		
	114			21·2							8·6		
	115			27·1							9·3		
	116			25·5							4·6		
	117			42·7							3·0		
	118			28·6							7·3	Surface absorption only.	
	119			35·4							2·6		
	120			32·2							6·6		
	121			33·6							4·3		
	122			41·5							7·0		
	123			35·6							6·3		
	124			17·5							8·6		
	125			14·7							12·0		
	126			15·2							8·6		
	127			21·2							7·3		
	128			30·0							7·0		
	129			50·4							6·0	Sapwood 30 per cent. complete. Heartwood $\frac{1}{16}$ inch to $\frac{1}{4}$ inch.	
AVERAGE	..	.	..	30·1	..	..	.	..	..	.	6·0		

APPENDIX III—*concld.*

Experiment VII.

Name of timber.	No	Process used	Oil used	Per cent moisture content at time of treatment	S G of air dried wood	Vacuum applied before treatment and time	Maximum press in applied and duration	Vacuum applied after treatment and time	Temperature range during treatment	Gross absorption lbs per c ft	Nett absorption lbs per c ft	Penetration as determined by boring or splitting	Remarks and how disposed of
Shorea assamica	130	Full cell	Creosote 25 per cent Earth Oil 75 per cent	2 ·0	·86	16 inches for 56 minutes	100 lbs per square inch for 45 minutes	15 inches for 15 minutes	155° to 170° F	4·8	5·0	In an average sleeper, surface treatment on the sides. Sap complete, end penetration 2 to 3 inches	
	131			1· 5							4·3		
	132			22·7							2·6		
	133			20·2							5·6		
	134			20·9							7·6		
	135			22·1							4·6		
	136			25·2							3·3		
	137			25·2							4·0		
	138			15·7							2·3		
	139			18·9							4·6	Sap complete, side $\frac{1}{16}$ inch, end 2 inches to 3 inches	
	140			18·7							3·0		
	141			18·6							4·3		
	142			17·2							4·6		
	144			2 ·7							5·3		
	145			17·5							10·3		
	146			22·5							5·3		
	147			23·2							4·0		
	148			16·7							2·6		
	149			11·6							6·0		
	150			33·2							2·6		
	151			15·8							6·3		
	152			15·3							7·3		
AVERAGE .				20·4							4·8		

Experiment VIII.

Shorea assamica	143	Lowry	Creosote 25 per cent Earth Oil 75 per cent	15 9	0	17 lbs per square inch for 1 hour 25 Minutes		15 inches for 20 minutes	175° to 180° F	5°0	6·6	End 8 inches, side ½ inch. Surface treatment, end 6 inches
	153			25 8							4 3	
	154			17 5							5 3	
	155			28 2							2 6	
	156			22 9							4·6	
	157			27 1							4 3	
	158			21 7							4·3	
	159			[illegible]							4·0	
	160			26·9							4 3	
	161			23 3							7 3	
	162			24 4							4 3	
	163			25·0							2 3	
	164			20 1							6·3	
	165			31 7							4 3	
	166			21 7							6 6	
	167			24 1							6 3	
	168			19 8							2 6	
	169			25 4							5·0	
	170			25 0							7·0	
	171			20 [illegible]							5 3	
	172			32 8							5 3	
AVERAGE				26 [illegible]							4 9	

APPENDIX IV.

Name of timber.	No.	Process used.	Oil used.	Per cent. moisture content at time of treatment.	S. G of air dried wood	Vacuum applied before treatment and time.	Maximum pressure applied and duration.	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lbs. per c. ft.	Nett absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
						Experiment I.							
Dillenia indica.	4	Full Cell.	Creosote 25 per cent. Earth Oil 75 per cent.	16·7	·80	18 inches for 1 hour.	175 lbs per square inch for 1 hour.	14 inches for 20 minutes	190° to 195° F.	19·0	16·3	Complete	
	8			8·3							19·0		
	10			4·5							7·0		
	12			7·9							18·6		
	16			8·9							19·6		
	18			14·3							15·6		
	22			7·9							19·0		
	26			11·2							21·3		
	28			23·9							18·0		
	30			5·8							25·3		
	32			7·8							20·0		
	34			9·5							17·0		
	36			7·5							19·6		
	38			6·1							24·6		
	40			5·5							21·6		
	42			12·5							20·0		
	44			6·2							22·3		
	46			5·2							17·0		
	48			9·8							19·0		
	50			7·6							26·0		
	52			14·9							16·0		
	54			12·5							16·6		
	56			4·9							19·3		
	58			8·2							17·3		
AVERAGE	..	..	..	9·5	..	..	.	..	..	..	19·0		
						Experiment II.							
	60		per cent.	11·5							24·0	Complete penetration.	Sent to the A. B. Ry.
	62			10·6							17·6		
	64			15·3							18·0		
	66			17·7							22·6		
	68			7·4							20·3		

Dillenia indica.	70	Lowry.	Creosote 33 per cent. Earth Oil 67	11·1	·60	12 inches for 15 minutes.	175 lbs. per square inch for 40 minutes.	16 inches for 40 minutes.	175° to 195°F.		21·6		It appears to be difficult to extract oil by the Lowry Process; Rüping process may suit this wood well.
	72			6·0							21·3		
	74			9·8							20·0		
	76			10·9							19·3		
	78			12·1							15·0		
	80			10·7							17·8		
	82			7·0							15·6		
	84			4·4							23·0		
	86			7·4							20·0		
	88			15·8							24·6		
	90			9·0							19·6		
	92			8·5							21·6		
	94			7·7							17·3		
	96			11·6							17·3		
	98			17·6							12·0		
	100			13·2							13·0		
	102			6·6							13·0		
	104			12·8							14·6		
	106			15·9							16·0		
AVERAGE .	..	..	..	10·5	.	..	..	..	..	..	18·6		

Experiment III.

Dillenia indica.	110	Lowry.	Creosote 50 per cent. Earth Oil 50 per cent.	9·1	·60	*Nil.*	95 lbs. per square inch for 0 minutes.	15 inches for 40 minutes.	170° to 175°F.		14·6	Complete.	
	114			11·2							18·6		
	118			..							13·6		
	120			..							7·6		
	122			..							6·3		
	124			..							17·0		
	126			..							20·6		
	128			..							13·3		
	130			8·2							15·6		
	132			..							13·0		
	134			15·0							12·6		
	136			11·6							13·3		
	138			..							4·6		
	140			..							8·3		
	142			..							10·0		
	144			..							12·3		
	146			11·0							11·6		
	148			..							12·6		
	150			..							12·0		
	152			7·0							22·0		
	154			12·4							13·6		
	156			9·4							24·0		
	158			8·3							18·6		
AVERAGE .	..	..	..	10·8	..	..	..	..	..	..	13·7		

APPENDIX IV—*contd.*

Name of timber	No	Process used	Oil used	Per cent moisture content at time of treatment	S. G. of air-dried wood	Vacuum applied before treatment and time	Maximum pressure applied and duration	Vacuum applied after treatment and time	Temperature range during treatment	Gross absorption lbs per c. ft	Nett absorption lbs per c. ft	Penetration as determined by boring or splitting	Remarks and how disposed of.
						Experiment IV.							
Dillenia indica	1	Lowry.	Creosote 25 per cent Earth Oil 75 per cent	15 6	·60	Nil	50 lbs per square inch for 8 minutes	16 inches for 28 minutes	160° F.	12 lbs	9 6	Complete	Absorptions fairly uniform.
	3			7 7							10 3		
	5			12 8							9·0		
	7			14 8							6 3		
	9			10 5							8 3		
	11			11 7							10 6		
	13			11 9							10 3		
	15			10 5							9 6		
	17			10 7							10·0		
	23			8 3							12 0		
	25			14 1							8 3		
	27			5 8							10·0		
	29			12 5							9·6		
	31			12 3							8·0		
	33			18 9							7 6		
	35			9·0							14 3		
	37			13 0							8 6		
	39			11 5							13 6		
	41			10 2							9 0		
	43			11 6							15·8		
	45			18 1							5·8		
	47			11·0							7 6		
	49			14 8							10 6		
AVERAGE	..	..	..	12 7					.	..	9 8		
						Experiment V.							
	51		cent	18 8							8·3	No sleeper cut as with	
	53			16 3							13 6		
	55			16 2							13 3		
	59			19 5							6·3		

Dillenia indica	61	Lowry.	Creosote 33 per cent. Earth Oil 67 per cent.	23·3	60	Nil	25 lbs. per square inch for 10 minutes.	15 inches for 30 minutes.	170°F.	9·8	7·3	the high absorption of 9·5 lbs. per c. ft. all the sleepers should be completely impregnated.
	63			15·6							7·6	
	67			15·2							11·3	
	69			16·8							9·3	
	71			18·2							10·0	
	75			18·6							[illegible]·0	
	77			23·2							11·0	
	79			15·0							9·6	
	81			16·6							7·0	
	83			16·4							10·0	
	85			20·1							10·0	
	87			13·0							11·6	
	89			13·6							12·6	
	91			16·4							7·3	
	93			15·9							11·0	
	95			20·6							9·6	
	97			16·2							8·0	
	99			18·3							6·6	
	101			16·9							10·3	
AVERAGE	..	..	..	17·4		.	..	..	..	..	9·5	

Experiment VI.

Dillenia	103	Lowry.	Creosote 50 per cent. Earth Oil 50 per cent.	21·1	4·0	Nil	26 lbs. per square inch for 5 minutes.	10 inches for 45 minutes.	170 to 185 F.	10·0	6·3	No sleeper cut as from past experiments. It is certain that there would be complete penetration.
	107			17·4							11·3	
	109			24·4							9·3	
	113			19·1							6·3	
	115			20·2							9·6	
	117			20·8							10·6	
	119			19·4							10·6	
	121			16·9							10·3	
	123			15·8							9·3	
	125			30·0							9·0	
	127			19·4							7·0	
	129			16·6							11·3	
	131			20·8							9·0	
	133			15·5							10·0	
	135			13·4							9·0	
	137			22·2							7·3	
	139			18·0							7·0	
	141			16·3							9·0	
	143			22·6							7·6	
	145			19·6							10·3	
	147			17·1							11·0	
	149			19·2							6·3	
	151			15·7							12·3	
AVERAGE	..	..	..	19·3	..	..	..	..	..	..	9·1	

APPENDIX IV—*contd.*

Experiment VII.

Name of timber.	No.	Process used.	Oil used.	Per cent. moisture content at time of treatment.	S. G. of air-dried wood.	Vacuum applied before treatment and time.	Maximum pressure applied and duration.	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lbs. per c. ft.	Nett absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Dillenia indica	153	Lowry.	Pure Creosote.	16·6	·60	*Nil.*	15 lbs. per square inch for 25 minutes.	15 inches for 30 minutes.	180°F.	10·0	8·6	It was not necessary to cut the sleepers for penetration as even with an absorption of 6 lbs. per c. ft. the penetration with the wood has been found to be thorough.	
	155			10·8							9·6		
	157			11·6							13·3		
	159			13·2							10·0		
	160			13·5							10·6		
	161			12·3							14·6		
	162			15·2							11·3		
	163			13·7							14·6		
	164			15·8							10·0		
	165			13·4							9·0		
	T. T. Specimens 1			20·0							8·3		
	2			15·9							8·6		
	3			16·1							10·6		
	4			16·9							10·6		
	5			20·0							7·6		
	6			18·1							6·3		
	7			11·1							11·3		
	8			18·9							6·3		
	9			23·5							8·3		
	10			18·3							12·0		
AVERAGE	..	..	..	15·7	..	..	..	..	..	..	10·7		

APPENDIX V.

Experiment I.

Name of timber.	No.	Process used.	Oil used.	Per cent. moisture content at time of treatment	S. G. of air-dried wood	Vacuum applied before treatment and time	Maximum pressure applied and duration	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lbs. per c. ft.	Nett absorption lbs. per c. ft.	Penetration as determined by boring or plitting.	Remarks and how disposed of.
Bischofia javanica	1	Full Cell.	50 per cent. Creosote 50 per cent. Earth Oil.	16·8	·08	15 inches for 30 minutes.	175 lbs per square inch for 1 hour and 30 minutes.	13 inches for 20 minutes.	160°F to 180°F.	6 lbs.	7·3	40 per cent. sap complete; heart, surface, end 1". 30% sap complete end ½" to 1½" side nil.	*Note.*—Absorption of the antiseptic ceased after the first 65 minutes. It is difficult to grade these sleepers into sap and heart wood sleepers respectively by usual inspection as in the case of pine sleepers. The sap treats easily but the heart does not take even 1lb. per c. ft. after 2 hours' pressure of 175 lbs. per sq. inch.
	2			15·0							6·0		
	3			15·9							6·7		
	4			15·4							7·0		
	5			24·0							5·7		
	8			18·9							2·7		
	9			21·6							5·7		
	10			16·5							4·7		
	11			26·0							2·[illegible]		
	12			15·0							9·0		
	13			17·7							5·7		
	14			19·1							9·7	60 per cent. sap complete; heart, surface, end 1 inch. 10% sap complete, end ½ inch to 1 inch; side, surface.	
	15			19·5							2·7		
	16			16·1							7·7		
	18			19·4							3·7		
	19			18·6							4·7		
	20			13·0							9·7		
	21			21·8							2·0		
	22			19·9							7·3		
	23			28·2							4·3		
	24			22·4							4·0		
	25			18·4							3·3		
AVERAGE .	..	..	..	19·0	..	.	.	..	..	..	5·4		

APPENDIX V—*contd.*

Experiment II.

Name of timber.	No.	Process used.	Oil used.	Per cent moisture content at time of treatment	S. G. of air-dried wood.	Vacuum applied before treatment and time.	Maximum pressure applied and duration	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lbs. per c. ft.	Nett absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Bischofia javanica	17	Lowry.	Creosote and Earth Oil in equal proportion.	17·0	·64	Nil.	175 lbs. per square inch for 2 hours	15 inches for 20 minutes.	170°F to 195°F.	6·7	8·[illegible]	50 per cent. sap. Heart, surface; sap complete; end 1 inch.	
	26			18·[illegible]							1·6		
	28			17·4							5·3		
	29			12·3							7·7		
	30			20·9							2·0		
	31			22·6							5·0		
	32			25·7							5·7	25 per cent. sap. Heart surface, sap complete, end in heart 1 inch.	
	33			19·6							2·7		
	34			20·1							4·7		
	35			21·5							4·3		
	36			21·8							6·0		
	37			12·6							3·3		
	38			13·9							6·0		
	39			12·9							6·0		
	40			14·9							5·3		
	41			16·2							1·3	No sap; badly cracked and the little absorption due to cracks.	
	42			15·6							6·6		
	43			11·7							9·0		
	44			14·4							1·[illegible]		
	45			14·3							2·0		
	46			15·7							2·7	10 per cent. sap, complete; heart, surface, end 1 inch.	
	47			13·3							4·7		
	48			16·0							3·3		
AVERAGE	..	..		16·9	.	..		..	..	..	4·2		

Experiment III.

Bischofia javanica.	49	Full Cell.	Creosote 33 per cent. Earth Oil 67 per cent	15·3	65	16 inches for 20 minutes.	175 lbs. per square inch for 1 hour 10 minutes	18 inches for 15 minutes.	170° to 180°F.		5·0		Bad lot of sleepers, nearly all cracked badly.
	50			18·4							6·0	40 per cent. sap; side *nil* end ½ inch.	
	51			18·7							4·3		
	52			17·3							4·8		
	53			19·3							[illegible]		
	54			22·5							3·0		
	55			19·2							3·3		
	56			16·3							0·7		
	57			15·3							[illegible]		
	58			17·5							4·7		
	59			20·5							2·0		
	60			22·0							4·3	20 per cent. sap ½ inch to 1 inch, side *nil*.	
	61			17·0							3·0		
	63			23·6							[illegible]		
	64			13·0							0·0		
	65			17·6							2·0	5 per cent. sap. Heart *nil* end 1 inch. Surface treatment except for sap.	
	67			14·8							0·0		
	68			17·9							8·0	60 per cent. sap, end ½ inch, side *nil*.	
	70			24·3							5·7		
	71			14·2							0·7		
AVERAGE	..	..	..	18·3	..	..	..	..	..	..	3·4		

(The sapwood appears to absorb oil at low pressure and the heartwood nothing, even at 175 lbs. pressure for a protracted period.)

APPENDIX V—*contd.*

Experiment IV.

Name of timber.	No.	Process used.	Oil used.	Per cent. moisture content at time of treatment.	S. G. of air-dried wood.	Vacuum applied before treatment and time	Maximum pressure applied and duration.	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lbs. per c. ft.	Nett absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Bischofia javanica.	72	Lowry.	Creosote 33 per cent. Earth Oil 67 per cent.	21·9	·64	*Nil.*	175 lbs. per sq. inch for 1 hour 10 minutes.	inches for 25 minutes.	160° to 180°F.	6·3	6·7		As observed in the previous charge the absorption of the antiseptic by the sapwood takes place at low pressure and the heartwood is very refractory to treatment even at high pressure.
	73			16 8							2·0		
	74			13·6							4·0		
	75			13·2							2·0		
	76			14·2							6·3		
	77			16·2							3·3		
	79			13·9							5·0		
	80			13·4							4·7	3 per cent. sap side *nil*, end ½ inch.	
	81			18·4							1·0		
	83			21·0							1·0		
	85			12·8							5·0		
	87			11·5							8·3	50 per cent. sap; heart *nil*, end 1 inch (badly cracked) oil occluded in crack.	
	88			18·1							2·3		
	89			16·9							7·0		
	90			11·7							5·0		
	91			10·6							6·0	60 per cent. sap; heart *nil*, end 1 inch.	
	92			13·4							5·0		
	93			12·9							5·0		
	94			13·6							3·3		
	95			13·2							1·6		
	96			13·0							6·3		
AVERAGE . .	..	..	..	14·8	..	..	..	..	..	..	4·3		

Experiment V.

Bischofia javanica	97	Lowry.	Creosote 25 per cent. Earth Oil 75 per cent.	12·9	·64	*Nil.*	170 lbs. per square inch for 50 minutes.	17 inches for 20 minutes.	180° to 185°F.	5·5	6·7	40 per cent. sap. Heart 1/16 inches to 1/8 inch.	
	98			23·8							5·3		
	99			14·3							6·0		
	100			14·6							5·3		
	101			22·4							4·0		
	102			17·7							5·7		
	103			14·5							4·7		
	104			17·8							4·7		
	105			18·3							3·7		
	106			14·5							3·3		
	107			18·8							1·7		
	108			16·9							9·0		
	109			7·5							2·0		
	110			36·4							4·3		
	111			14·0							6·0		
	112			17·1							4·3		
	113			20·2							2·7		
	114			16·4							8·0		
	115			19·4							1·7		
	116			15·2							2·3		
	117			16·6							4·3		
	118			17·8							5·0		
	119			13·4							2·7	10 per cent. sap. Heart 1/16 inch to 1/8 inch.	
AVERAGE .	..	..	..	17·4	..	..	..	..	..	..	4·5		

Experiment VI.

Bischofia javanica	120	Lowry.	Pure Creosote.	16·5	·67	*Nil.*	175 lbs. per square inch for 1 hour	15 inches for 20 minutes.	200°F.	6·5	5·7		To the A. B. Ry.
	121			16·0							2·0		
	122			15·4							6·7		
	123			13·2							6·0		
	125			16·6							2·3		
	126			19·4							6·0	45 per cent. sap. Side 1/16 inch to 1/8 inch.	
	127			15·3							5·3		
	128			15·9							2·7		
	130			12·8							5·3		
	131			16·1							2·3		
	132			16·6							1·3		
	133			25·2							4·7		
	134			18·0							12·0		
	135			18·5							6·0		
	136			19·0							3·0	15 per cent. sap. Heart 1/16 inch.	
	137			14·4							3·7		
	138			16·8							4·7		
	139			14·8							10·8	60 per cent. sap. Side 1/16 inch.	
	141			11·3							4·7		
	142			18·1							7·7		
AVERAGE .	..	..	..	16·5	..	..	..	..	..	..	5·1		

APPENDIX V—*contd.*

Experiment VII.

Name of timber.	No.	Process used.	Oil used	Per cent moisture content at time of treatment	S. G. of air-dried wood.	Vacuum applied before treatment and time.	Maximum pressure applied and duration.	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lbs. per c. ft.	Nett absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Bischofia javanica	T. T. Specimens. 1	Lowry.	Creosote (Pure).	22·6	·67	Nil.	175 lbs. per square inch for 1 hour.	16 inches for 20 minutes.	180°F to 185°F.	5·0	2·0	No penetration.	
	2			21·5							5·7		
	3			19·8							2·7		
	4			32·8							3·3		
	5			38·7							6·3		
	6			19·3							3·3		
	7			19·4							2·7		
	8			20·2							3·0		
	9			38·4							5·3		
	10			22·0							3·3		
	143			18·1							1·0		
	144			13·5							9·0		
	145			16·6							3·7		
	146			18·9							2·3		
	147			17·2							7·0		
	150			14·7							4·3		
AVERAGE .	..	..	..	21·8	..	..	..	..	..	..	4·05		

APPENDIX VI.

Experiment I.

Name of timber	No	Process used	Oil used	Per cent moisture content at time of treatment	S. G. of air dried wood	Vacuum applied before treatment and time	Maximum pressure applied and duration	Vacuum applied after treatment and time	Temperature range during treatment	Gross absorption lbs per c. ft	Nett absorption lbs per c. ft	Penetration as determined by boring or splitting	Remarks and how disposed of
Tor mincha myriocarpa	1	Lowry.	Creosote 25 per cent. Earth Oil 75 per cent	15·8	70	13 inches for 15 minutes	175 lbs per square inch for 35 minutes	16 inches for 30 minutes	105 steady (steam coil in pressure cylinder leaking and so cut off)	[illegible]6	6·7	Absorption of over 6 lbs. per c. ft almost complete penetration. End 7 to 8 inches. Heart all round 1 inch to 2 inches, sap complete	Very satisfactory. The wood treats well and promises to make a very good sleeper wood. The whole treatment should not take over 2 hours so that three to four charges of the wood may be treated in a day (in a commercial plant). Another point to note is the remarkable uniformity of absorption. Considerable absorption at 25 to 40 lbs and 125 to 130 lbs pressure
	2			12·9							7·3		
	3			14·9							9·0		
	4			15·3							7		
	5			12·0							7·7		
	6			13·6							7·7		
	7			11·0							10·0		
	8			12·7							8·7		
	9			10·4							8·0		
	10			7·9							9·3		
	11			14·5							7·3		
	12			30·1							8·0		
	13			7·3							7·0		
	14			10·7							8·7		
	15			11·6							8·3		
	16			16·6							6·0		
	17			11·8							9·0		
	18			17·8							7·3		
	19			10·2							8·3		
	20			19·6							7·3		
	21			20·3							8·0		
	22			13·0							8·3		
	23			10·0							8·7		
AVERAGE	..	..	..	13·9	.	..		.			8·0		

APPENDIX VI—*contd.*

Name of timber.	No.	Process used.	Oil used.	Per cent. moisture content at time of treatment.	S. G. of air-dried wood.	Vacuum applied before treatment and time.	Maximum pressure applied and duration.	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lbs. per c. ft	Nett absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
						Experiment II.							
Terminalia myriocarpa	24	Lowry.	Creosote 25 per cent. Earth Oil 75 per cent.	16·1	·65	Nil.	175 lbs. per square inch for 55 minutes.	15 inches for 20 minutes.	175° to 180°F.	8·6	7·6	Complete.	
	25			13·9							8·6		
	26			9·5							9·3		
	27			34·0							6·0		
	28			16·3							6·6		
	29			12·0							9·0		
	30			13·9							8·6		
	31			13·2							7·3		
	32			34·9							6·6		
	33			8·8							9·0		
	34			13·8							7·0		
	35			11·1							7·3	Complete.	
	36			15·8							7·3		
	37			10·8							8·0		
	38			21·2							6·0		
	39			13·3							8·3		
	40			9·4							7·3		
	41*			13·5							10·6		
	42			13·1							7·6		
	43			14·8							6·6		
	44			22·6							7·6		
	45			12·7							6·6		
	46			13·5							7·3		
AVERAGE	..	..	..	15·5	..	..	..	..	..	..	7·7		
						Experiment III.							
	47		cent.	15·2			minutes.				8·0	The species	The absorp-
	48			13·5							9·0	takes creo-	tions are
	49			11·3							9·3	sote thr-	very uni-
	50			14·7							7·66	ough and	form and
	51			13·3							10·66	through so	seem to be
	52			23·4							8·66	that cut-	a charac-

Terminalia procarpa.	53	Lowry.	Creosote and Earth Oil 50 per	11·2	·64	*Nil.*	175 lbs per square inch for 55	15 inches for 25 minutes	165° to 170°F.	12 lbs.	9·66	ting sleepers were dispensed with.	teristic of this wood.
	54			20 8							9·66		
	55			20·0							8·3		
	56			18 6							8·66		
	57			11·5							8·66		
	58			19·4							9·3		
	59			16 3							9·3		
	60			10 8							8·66		
	61			12·0							9·3		
	62			11 1							7·3		
	63			8 9							9·66		
	64			11·2							9·66		
	65			17·8							8·3		
	66			18 7							9·3		
	67			19 4							8·66		
	68			13·8							6·66		
	69			27 4							7·66		
AVERAGE .	..	..	..	15·7	..	..	..	..	..	..	8·8		

Experiment IV.

Terminalia myriocarpa.	70	Lowry.	Creosote 50 per cent. Earth Oil 50 per cent.	21 1	·64	*Nil.*	175 lbs. per square inch for 1 hour.	16 inches for 20 minutes.	170°F.	8	9 3	
	71			16·5							6·7	
	72			25 9							8·0	
	73			39·9							6·0	
	74			27 9							8·3	
	75			49·5							7·7	
	76			11·6							8·7	
	77			14 3							7·7	
	78			13 5							6·7	
	79			22 6							9 7	
	80			29 8							8.0	
	81			32 5							7·0	
	82			12·2							9·0	
	83			15·0							9·3	
	84			11 5							10·3	
	85			15·0							8 7	
	86			12·0							8·7	
	87			14·3							9·3	
	88			14 8							7·3	Complete.
	90			12 5							7·7	
	91			17·8							7·3	
	92			36·4							8·0	
AVERAGE .	..	..	..	21·2	..	..	..	..	..	..	8·1	

APPENDIX VI—*contd.*

Experiment V.

Name of timber.	No.	Process used.	Oil used	Per cent. moisture content at time of treatment.	S. G. of air-dried wood.	Vacuum applied before treatment and time	Maximum pressure applied and duration.	Vacuum applied after treatment and time	Temperature range during treatment	Gross absorption lbs. per c. ft.	Nett absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Terminalia myriocarpa.	93	Lowry.	Creosote 33 per cent. Earth Oil 67 per cent.	14·1	·70	*Nil.*	175 lbs. per square inch for 1 hour.	17 inches for 20 minutes.	160°F to 175°F.	9 lbs.	5·7	Complete.	The sleeper with the lowest absorption was cut, and it was found to have oil through and through.
	94			14·1							5·7		
	95			14·0							6·0		
	96			12·3							8·0		
	97			14·2							6·0		
	98			15·3							7·3		
	99			18·8							5·7		
	100			19·2							9·7		
	101			15·1							8·3		
	102			15·2							6·7		
	103			14·7							7·0		
	104			17·9							5·3		
	105			25·2							6·0		
	106			17·6							6·0		
	107			19·7							5·0		
	108			8·2							7·7		
	109			21·1							5·7		
	110			14·2							5·7		
	111			28·0							7·0		
	112			15·6							5·3		
	113			16·8							6·7		
	114			14·2							7·3		
	115			14·7							6·3		
AVERAGE	..	..	..	16·5	..	..	..	..	..	..	6·5		

Experiment VI.

Terminalia myriocarpa.	116	Lowry.	Creosote 33 per cent. Earth Oil 67 per cent.	22·6	·71	*Nil.*	165 lbs. per square inch for 1 hour.	17 inches for 20 minutes.	170°F to 180°F.	7·8	6·7		The absorptions are very uniform.
	117			11·4							6·7		
	118			12·4							8·7		
	119			19·0							7·3		
	120			14·9							7·0		
	121			17·6							6 7	Complete.	
	122			12·4							7·3		
	123			16·1							7·0		
	124			12·0							8·3		
	125			21·1							7·3		
	126			17·5							7·3		
	127			10·7							7·8		
	128			17·0							6·0		
	129			14·7							7·3		
	130			20·1							7·0		
	131			21·0							8·0		
	132			22·8							6·3	Complete.	
	133			14·8							7·7		
	134			12·9							8·0		
	135			11 7							6·7		
	136			24.6							8·3		
	137			13·7							7·0		
AVERAGE	..	..	..	16·4	..	..	..	..	..	..	7·3		

Experiment VII.

Terminalia myriocarpa. T. T. Spec men.	1	Lowry.	Creosote (Pure).	15·0	·73	*Nil.*	175 lbs. per square inch for 1 hour.	15 inches for 25 minutes.	180° to 185°F.	..	9 3		
	2			17·6							7·7		
	3			20 2							10·0		
	4			22 7							10 3		
	5			23·0							9 6		
	6			24·0							12 3		
	7			21 8							5 3		
	8			19 9							8·0		
	9			18·7							10 3		
	10			15 6							8 0		
	139			27 8							10 7		
	140			12 9							11·0	Complete.	
AVERAGE	..	..	..	20·3	..	..	..	..	..	..	9 3		

APPENDIX VI—*contd.*

Experiment VIII.

Name of timber.	No.	Process used.	Oil used.	Per cent. moisture content at time of treatment.	S. G. of air-dried wood.	Vacuum applied before treatment and time.	Maximum pressure applied and duration.	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lbs. per c. ft.	Nett absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Terminalia myriocarpa.	141	Lowry.	Pure Creosote.	10·1	·69	*Nil.*	175 lbs. per square inch for 1 hour.	16 inches for 25 minutes.	180° to 190°F.	9·0	8·0	Complete.	To the A. B. Ry.
	142			21·3							10·3		
	143			10·2							9·3		
	144			21·4							9·0		
	145			13·8							8·0		
	146			14·8							8·7		
	147			12·0							9·0		
	148			17·3							8·3		
	149			19·1							9·0		
	150			21·8							10·0		
	151			12·5							7·7		
	152			16·1							8·3		
	153			11·0							9·7		
	154			15·7							7·0		
	155			14·1							7·3		
	156			25·4							8·7		
	157			16·5							9·3		
	158			12·7							11·0		
	159			12·1							7·3		
	160			24·1							5·7		
	161			14·8							8·3		
	162			25·7							9·3		
AVERAGE .	..	..	..	16·4	..	..	..	..	..	..	8·6		

APPENDIX VII.

Experiment I.

Name of timber.	No.	Process used.	Oil used	Per cent moisture content at time of treatment.	S. G. of air-dried wood.	Vacuum applied before treatment and time	Maximum pressure applied and duration.	Vacuum applied after treatment and time	Temperature range during treatment.	Gross absorption lb. per c. ft	Nett absorption lbs. per c. ft	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Lagerstroemia Flos-Reginae.	1	Lowry.	Creosote 50 per cent. Earth Oil 50 per cent.	27·5	·64	*Nil.*	175 lbs. per square inch for 2 hours 50 minutes.	16 inches for 25 minutes.	170 to 175°F.	1·7 lbs.	0·0		The wood appears to be very refractory to creosote treatment.
	2			13·3							0·0		
	3			15·7							1·0		
	4			15·8							1·3		
	5			29·8							1·3		
	6			16·2							2·0		
	7			14·3							1·3		
	8			13·2							2·3		
	9			11·9							0·7		
	10			20·8							2·0		
	11			14·9							0·0		
	12			21·0							1·0	End 1 inch, side almost *nil*, surface only.	
	13			24·1							0·0		
	14			25·9							0·0		
	15			21·9							1·0		
	16			23·4							0·0		
	17			14·4							0·3		
	18			12·0							0·0		
	19			12·3							1·0		
	20			28·3							1·0		
	21			15·5							0·3	Side $\frac{1}{16}$ inch and $\frac{1}{8}$ inch, end 1 inch	
	22			14·5							2·7		
	23			13·4							0·0		
AVERAGE .	..	..	..	18·3	..	..	..	..	..	..	0·84		

APPENDIX VII—*contd.*

Experiment II.

Name of timber.	No.	Process used.	Oil used.	Per cent. moisture content at time of treatment.	S. G. of air-dried wood.	Vacuum applied before treatment and time.	Maximum pressure applied and duration.	Vacuum applied after treatment and time.	Temperature range during treatment.	Gross absorption lb. per c. ft.	Nett absorption lbs. per c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Lagerstroemia Flos-Reginae.	25	Boiling under vacuum of 13 inches to 15 inches for 24 hours at 200°F and then Full Cell process.	Creosote and Earth Oil in equal proportion.	30·2	·61	15 inches for 24 hours.	175 lbs. per square inch for 1 hour.	15 inches for 20 minutes.	175°F to 190°F.	0·75 lbs.	0·3		The wood is very refractory to treatment.
	26			14·2							1·3		
	27			15·4							1·0		
	28			28 9							0·3		
	29			17 8							1·3		
	30			22·7							0·0		
	31			27·8							0·0		
	32			30·4							0·0		
	33			18·5							1·6		
	34			17·2							0·6		
	35			16·2							0·3		
	36			21·9							0·0		
	37			20·2							0·6		
	38			16·4							1·3		
	39			13·8							1·0		
	40			24·2							0·6		
	41			17·9							0·0		
	42			17·9							0·0		
	43			19·2							1·3		
	44			12·1							2·3		
	45			24·9							0·3		
	46			19·2							1·3		
	47			20·8							1·0	Sap complete, surface treatment, end 1 inch.	
AVERAGE	..	..	..	20·3	..	..	..	..	..	..	·75		

Experiment III.

Lagerstroemia Flos-Reginæ.	·48	Boiling for 4 hours, at 180°F.	Creosote 50 per cent. Earth Oil 50 per cent.	..	·64	*Nil.*	*Nil.*	15 inches for 30 minutes.	180°F.	..	1·0
	49			..							1·3
	51			..							0·3
	52			..							1·3
	53			..							1·0
	54			..							0·6
	55			..							1·6
	56			..							0·6
	58			..							0·6
	59			..							1·3
	60			..							1·0
	61			..							0·6
	62			..							1·0
	63			..							1·0
	64			..							1·0
	65			..							1·0
	66			..							1·0
AVERAGE .	..	..	..	..	..	..	..	..	..	..	0·9

Experiment IV.

Lagerstroemia Flos-Reginæ.	67	Boiling for 4 hours, at 180°F.	Creosote 50 per cent. Earth Oil 50 per cent.	..	·60	*Nil.*	*Nil.*	12 inches for 30 minutes.	190°F.	..	0·6
	68			..							0·3
	69			..							0·6
	70			..							0·6
	71			..							0·6
	72			..							0·6
	73			..							0·6
	74			..							0·6
	75			..							0·3
	76			..							0·3
	77			..							0·6
	78			..							0·6
	79			..							1·0
	80			..							1·0
	81			..							1·0
	82			..							1·3
	83			..							0·6
AVERAGE .	..	..	..	..	..	..	..	..	..	..	0·7

Appendix VII—*contd.*

Experiment V.

Name of timber	No	Process used	Oil used	Per cent moisture content at time of treatment	S. G. of air-dried wood	Vacuum applied before treatment and time	Maximum pressure applied and duration	Vacuum applied after treatment and time	Temperature range during treatment	Gross absorption lbs. per c. ft.	Nett absorption lbs. c. ft.	Penetration as determined by boring or splitting	Remarks and how disposed of.
Lagerstroemia Flos-Reginae.	84	Boiling under vacuum for 3 hours and then 1 hour pressure up to 175 lbs.	Creosote 50 per cent. Earth Oil 50 per cent.	..	·57	20 inches for 3 hours.	175 lbs. per square inch for 1 hour.	20 inches for 1 hour.	175°F.	2·6 lbs	0·66		
	85			..							1·0		
	86			..							0·66		
	87			..							1·3		
	88			..							1·3		
	89			..							1·3		
	90			..							1·0		
	91			..							1·3		
	92			..							0·66		
	93			..							1·0		
	94			..							0·33		
	95			..							1·0		
	96			..							1·6		
	97			..							0·66		
	98			..							0·66		
	99			..							0·66		
	100			..							1·0		
	101			..							1·6		
	102			..							0·66		
	103			..							0·66		
	104			..							1·3		
	105			..							0·66		
Average	..	..	..	..	..	..	..	..	..	..	·95		

Experiment VI.

Lagerstræmia Flos-Reginæ.	106	Boiling under vacuum for 3 hours and then 1 hour pressure up to 175 lbs.	Creosote 50 per cent. Earth Oil 50 per cent.	..	·58	20 inches for 3 hours.	175 lbs. per square inch for 1 hour.	20 inches for 45 minutes.	175° F.	3·3 lbs.	1·0
	107			..							0·66
	108			..							1·3
	109			..							1·6
	110			..							1·0
	111			..							0·33
	112			..							1·0
	114			..							2·3
	115			..							1·3
	116			..							2·0
	118			..							1·0
	119			..							1·0
	120			..							0·66
	121			..							1·0
	122			..							1·0
	123			..							1·3
	124			..							1·6
	125			..							0·66
	126			..							1·0
	127			..							1·3
	128			..							1·0
	129			..							1·0
AVERAGE ..	..	..	..	..	..	..	..	..	..	..	1·1

Experiment VII.

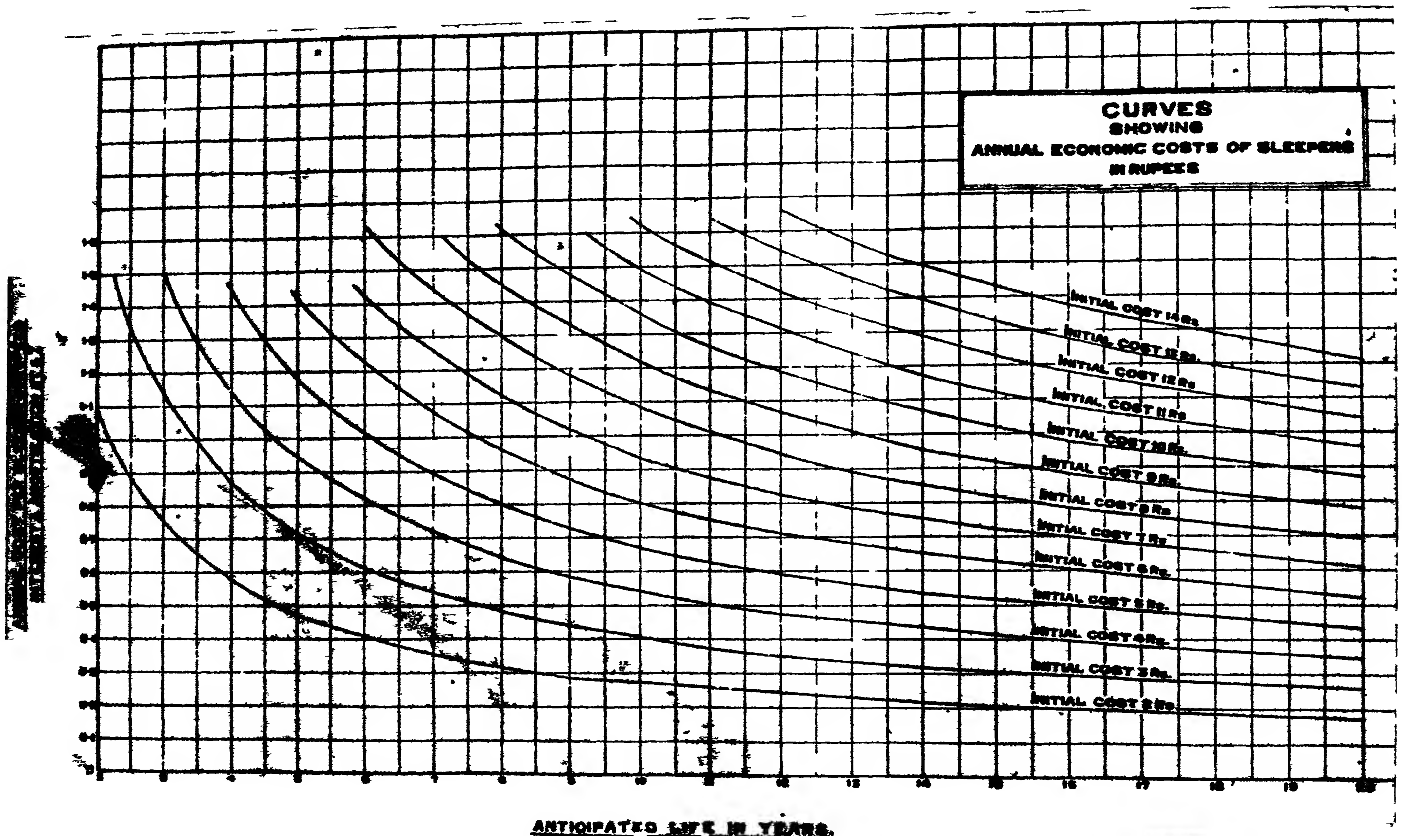
Lagerstræmia Flos-Reginæ.	130	Full Cell.	Creosote 50 per cent. Earth Oil 50 per cent.	14·5	·58	22 inches for 45 minutes.	175 lbs. per squar inch for 3 hours.	20 inches for 15 minutes.	160° F.	4 lbs.	1·6
	131			12·1							1·3
	132			12·9							1·6
	133			20·4							1·0
	134			23·9							2·0
	135			16·8							2·0
	136			21·8							0·66
	137			17·0							1·6
	138			11·9							0·66
	139			14·4							3·6
	140			16·6							1·6
	141			18·5							1·0
	142			32·3							2·3
	143			15·6							2·3
	144			27·1							1·3
	145			14·9							1·6
	146			25·8							1·0
	147			15·4							1·6
	148			27·4							1·0
	149			15·7							2·0
	150			..							1·0
	151			15·4							1·6
AVERAGE ..	..	..	..	18·6	..	..	..	..	..	..	1·5

G

APPENDIX VII—*contd.*

Experiment VIII.

Name of timber.	No.	Process used.	Oil used	Per cent moisture content at time of treatment.	S. G of air-dried wood.	Vacuum applied before treatment and time	Maximum pressure applied and duration.	Vacuum applied after treatment and time	Temperature range during treatment	Gross absorption lbs. per c. ft.	Nett absorption lbs. c. ft.	Penetration as determined by boring or splitting.	Remarks and how disposed of.
Lagerstræmia Flos-Reginae.	152	Full Cell	Pure Creosote.	6·6	60 L. F. R.	26 inches for 45 minutes.	175 lbs. per square inch for 2 hours 15 minutes.	20 inches for 20 minutes.	165° F.	Composite charge and so not known.	1·0		
	153			18·3							1·4		
	154			14·1							2·6		
	155			17·8							1·6		
	156			15 9							2·0		
	157			22·7							0·66		
	158			16·4							1·3		
	159			17·3							1·6		
AVERAGE	..	..	.	16·1	..						1·8		
Vateria indica for Timber Testing Section.	1	Full Cell.	Pure Creosote	13·0	·56 V. I.						..		
	2			12·9							..		
	3			12·4							..		
	4			12·6							..		
	5			12·5							..		
	6			12·5							..		
	7			17·9							..		
	8			11·9							..		
	9			12·7							..		
AVERAGE	..	..	..	13·2	..	..	..	..	..	..	..		


CURVES
SHOWING
ANNUAL ECONOMIC COSTS OF SLEEPERS
IN RUPEES
INITIAL COST 14 Rs.
INITIAL COST 12 Rs
INITIAL COST 11 Rs
INITIAL COST 9 Rs.
INITIAL COST 8 Rs
INITIAL COST 7 Rs
INITIAL COST 6 Rs.
INITIAL COST 5 Rs.
INITIAL COST 4 Rs.
INITIAL COST 3 Rs.
INITIAL COST 2 Rs.
ANTICIPATED LIFE IN YEARS.

CHAPTER II.

Cost of Treatment.

i. GENERAL DISCUSSION.

The cost of treatment naturally depends upon several factors, the chief of which are the cost of the antiseptic and the cost of the plant.

With regard to cost of the antiseptic, only generalisations can be made, as this naturally varies with different localities and also in accordance with the market. Due weight must also be given to the protection obtained and the length of life which the antiseptic to be chosen will ensure for each species.

It is perfectly true to say that the most economical antiseptic is the one which will protect the timber from decay and insect attack just so long as it will last mechanically. As to the mechanical life of a sleeper, some of the species treated in this series of experiments were treated in a former series of experiments, and these data, together with figures obtained in the Timber Testing shops, allow us to frame an approximate estimate of the mechanical life of some of the timbers However, the only reliable method is to test the sleeper under service conditions. Naturally, this test takes a considerable time to complete, and alterations in procedure may often become necessary in the light of experience and better knowledge.

It is therefore not possible to say, at this juncture, which of the mixtures, used in the experiments described in Chapter I, will prove most economical in the long run.

In order to grasp readily the relative economic value of a sleeper, a series of curves have been prepared, which, for a capital expenditure of a certain number of rupees, shew the annual cost to be set aside to provide for it at 6 per cent interest, on the assumption that the useful life in years is known.

To read these curves, a vertical line is drawn through the number indicating the life in years (horizontal bottom line) to where it cuts the curve corresponding to the capital cost of the finished sleeper; from this point a horizontal line is drawn to cut the vertical line representing annual cost in rupees. Intermediate values are obtained by interpolation. As an example a *Pinus longifolia* (*chir*) B G. sleeper costs approximately Rs. 6-8 when preserved with equal parts of Creosote and Earth Oil. It is known to last, on an average, for 12 years, which according to the curve gives Rs. 0·77 as the annual cost; whereas an untreated *Shorea robusta*

(*sal*) B. G. sleeper, which costs Rs. 8 and lasts 18 years, gives an annual cost of Rs. ·74. To give the same annual cost treated '*chir*' at Rs. 6-8 would require an average life of nearly 15 years.

Cedrus Deodara (deodar), untreated, costing Rs. 7-8 and lasting for 14 years, gives almost the same annual cost as '*chir*,' which is therefore an alternative proposition.

The choice, therefore, of an antiseptic depends upon the relative importance of its first cost and efficiency, which latter can only be ascertained by treating different species of sleepers and carrying out durability tests.

In more temperate climates, unadulterated Creosote out-distances its cheaper rivals on account of its great efficiency, but it remains a moot point as to whether it will do so in India, where the climatic factors are of much greater intensity.

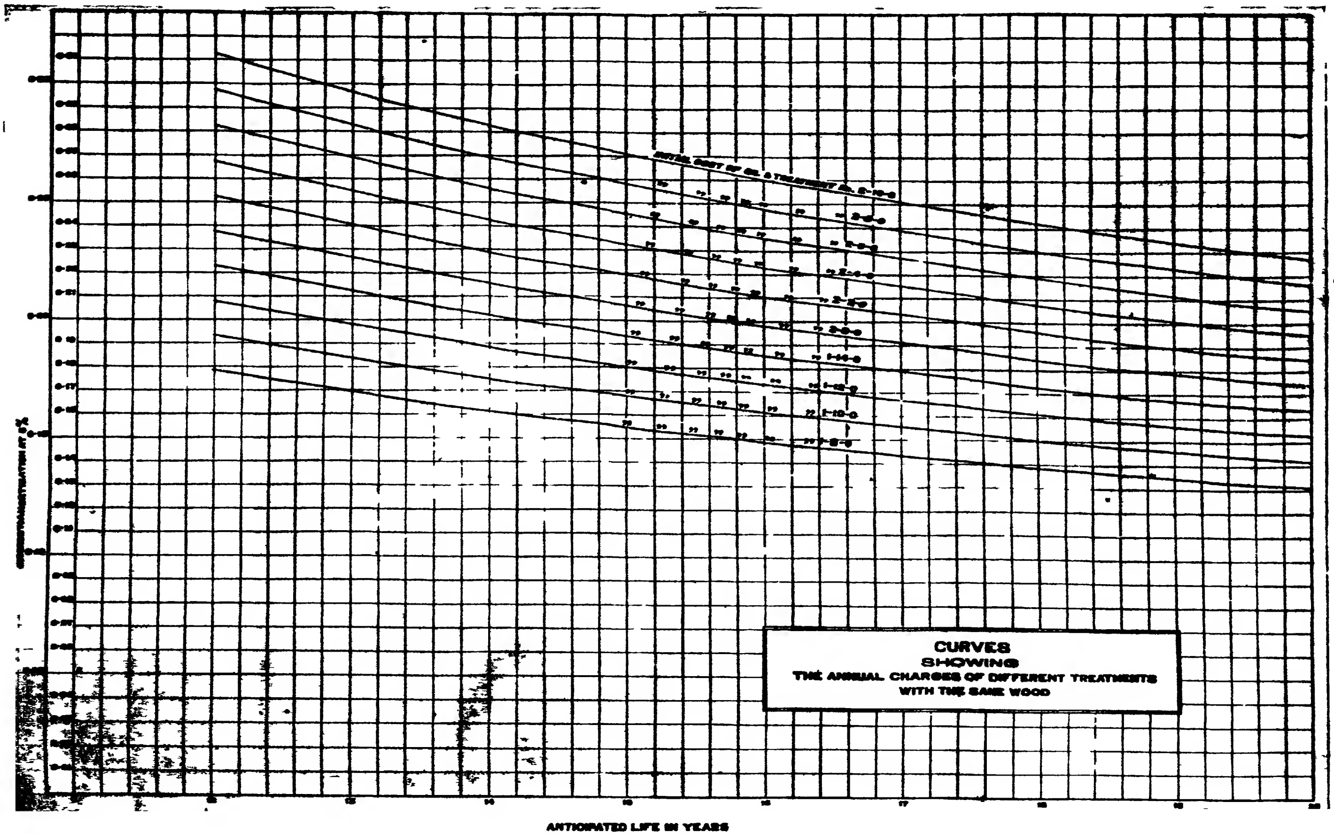
ii. ECONOMIC LIMITS OF TREATING PLANTS.

The capital cost of the plant to be used is another important item, as this accounts for about 50 per cent. of the operating costs. The plant must, therefore, be carefully designed so as to ensure smooth working and continuity of output, bearing in mind that the charges for capital cost are inversely proportional to the output, whereas the capital cost of the plant increases with its capacity, less, however, than in the direct ratio.

The capacity of the plant is, moreover, dependent on the rate of treatment advisable and is here based on the assumption that three charges per day can be worked commercially. This rate will vary with the species treated. For instance, with the *Dipterocarpus* family, as many as four charges per day may be treated ; but with *Lagerstrœmia Flos-Reginæ* probably only two charges could be worked in the same time.

The first question, therefore, to be answered is, what is the smallest pressure plant that it is economical to work and what area will it serve ? This naturally involves a knowledge of cost of transport (which will vary with different localities), since the amount expended in transport must be more than balanced by the saving in cost of treatment by a big plant, over the cost of treatment in one of smaller capacity. The sleepers would, of course, be floated to the treating plant wherever possible, as water-borne transport is much cheaper than other means available ; but, unfortunately, reliable waterways are difficult to find in India, with the result that calculations must usually be based on railway transport.

Again, it can be estimated that a plant to deal with 500,000 B. G. sleepers working 3 or 4 charges per day will save 2 annas per sleeper over


CURVES
SHOWING
THE ANNUAL CHARGES OF DIFFERENT TREATMENTS
WITH THE SAME WOOD
ANTICIPATED LIFE IN YEARS

a plant treating 100,000 B. G. sleepers at the same rate, but if this money is expended in extra railway freight in collecting the sleepers to supply the larger plant, it is obviously more economical to erect a number of smaller plants, always bearing in mind the possibility of the smaller area being able to supply a larger number of sleepers in the future. This contingency can, of course, be met by installing a second cylinder, but the cost of treatment will never be quite so low as that obtained in a large single cylinder plant.

An apparatus to treat 100,000 B. G. sleepers will necessitate a cylinder of from 36 to 40 ft. in length, and the pumps and boiler necessary to work it are of the smallest commercial size, consistent with efficiency; it may therefore be stated that this pressure plant is the smallest which can be economically worked and forms the basis of subsequent calculations. Its capacity for metre gauge work is double that of its B. G. capacity.

The area which such a plant will serve, naturally, depends upon the yield of sleepers from the neighbouring forests, basing estimates on the sum of all treatable species.

According to the Report of the Sleeper Enquiry Committee, 1923-24, 2½ pies per ton mile is the normal rate for railing sleepers. If we take 30 M. G. or 15 B. G. sleepers to the ton as an average for timber we find that the saving in cost of treatment (2 annas per B. G. sleeper) is used up in railing the sleepers 150 miles and it can therefore be assumed that a smaller plant will be more economical than the larger one if collection of supplies has to be made over a larger area than say 150 miles on either side of the plant, along the railway ; or a total length of line of 300 miles. Assuming 2,000 sleepers per mile and the normal replacement of treated sleepers as 7 per cent. (15 years' life) this length of line would require, for single track, about 50,000 sleepers annually.

A plant to deal with 100,000 B. G. or 200,000 M. G. sleepers could easily cope with this together with requirements for sidings, yards, etc.

If the above area is capable of yielding more than these numbers, a larger plant would obviously pay, especially if branch lines have to be provided for.

The position of the plant would, naturally, fall somewhere between the centre of area of supply and the centre of area of use of the sleepers, the exact spot depending upon convenience, taking into consideration the cost of transport of oil to the plant.

Pure forests, yielding sleeper woods, are seldom found in India, so that to make extraction economical, it is necessary to utilise as many as possible of the species which grow together. They, usually, cannot be treated together on account of the difference in their structure, and consequently of the ease with which they treat. As an example,

it would be folly to treat *Dillenia indica* in the same charge as *Lagerstrœmia Flos-Reginœ*, because, since *Dillenia indica* treats readily, it would take all the antiseptic, whereas the *Lagerstrœmia*, which treats with difficulty, would absorb little or none of the oil. On the other hand if the pressure is maintained until the *Lagerstrœmia* is protected, the *Dillenia indica* would have more preservative than is necessary or economically sound. The species must therefore be treated separately, each according to its specification.

iii. LAY-OUT OF PLANT.

It is almost an axiom that the success of a Wood Preserving Plant depends upon the correct lay-out of the stacking ground, so as to ensure that the treating cylinder is never idle for a moment. The best method of securing this is perhaps debatable, but a good arrangement is to have the stacking ground rectangular in shape with the treating cylinder about the middle of one long side, which may be parallel or at right angles to the main railway line.

Railway lines should run the whole length of the yard parallel to each other and to the long side of the yard, about 120 ft. apart if the system is Broad Gauge. In between these lines, should run the narrow gauge rails on which the treating trucks are hauled to the treating cylinders.

The problem is to arrange the lay-out so that minimum haulage and shunting is required, and also so as to avoid blocking the road for empty treating trains by loaded ones and *vice versa.*

If an adzing and boring machine is installed, the narrow gauge track will, of course, run in the most direct manner to it where the sleepers are machined and transferred to empty treating trucks.

In the case of Metre Gauge systems, the ordinary track run at 60 ft. centres will be sufficient to do all the yard work, the sleepers being transferred to treating trucks after passing through the adzing and boring machine.

iv. ADZING AND BORING.

The importance of adzing and boring before treatment cannot, from a wood preservation point of view, be too strongly emphasized, especially in those cases where impregnation is not complete; any removal of the preserved outer layer, by cutting the sleeper after treatment so as to expose untreated wood, provides a means of ingress to insects and fungus, and the efficacy of the treatment is, thereby, considerably impaired if not entirely destroyed. If an example is needed, one has only to refer to the results of experimental *Dipterocarpus* sleepers, which were bored

and adzed after treatment and laid in the main line near Ranaghat on the E. B. Railway These sleepers were taken out about 10 years after being laid down, the cause of rejection being entirely due to failure under the rail seat and round the spike hole, due to fungus attack. The ends and centre of the sleepers were perfectly sound, and had the adzing and boring been carried out before treatment, the sleepers would probably have lasted 13 or 14 years.

v. LOADING AND HANDLING SLEEPERS.

The question of haulage is best left to individual taste, but it is hardly likely that mechanical haulage will pay with a small plant. If a double-ended cylinder is installed, the loaded trains may be hauled in and out of the cylinder by a steam winch, placed at the exit end of the plant; bullocks or coolies can be made responsible for the remaining work. In the case of metre gauge systems, the ordinary locomotives could do the usual yard work and the winch be made responsible for hauling the trains from the adzing and boring machine, into and out of the cylinder, after treatment. The adzing and boring plant forms a very convenient break at which to transfer the sleepers from one system of track to the other, but some authorities contend that a metre gauge system is permissible inside the cylinder as the loss in capacity is compensated for by the convenience of being able to link up the cylinder to any portion of the yard. Thus the services of the yard locomotive are always available for hauling treated sleepers to any part of the stacking ground.

This arrangement certainly does aw with the necessity for a double-ended cylinder, but is only permissible with metre and narrow gauge systems.

With broad gauge systems, if no adzing and boring plant is installed, either a narrow gauge track must be run between the broad gauge tracks or the sleepers must be transferred at a convenient spot. It is doubtful if this latter alternative will save money in the long run, as interest and depreciation on rails can be put at about 3 pies per sleeper, whereas the cost of transfer will not be less than 3 pies per sleeper and, in addition, there is the risk of serious delay occurring at this point.

Treated sleepers should be handled with care and should be got out of the yard as quickly as possible, but if delay is unavoidable, they should be stacked close to the loading ground so as to avoid long leads. It is, however, mu h more economical to load them straight on to empty trucks as this avoids double handling.

The foregoing remarks seem perfectly obvious when put on record, but the points emphasized are too often neglected, with the result that

delays are occasioned, output falls off, and wood preservation is said not to pay.

vi. Capital Cost of Plant and Lay-out.

With regard to capital cost of Creosoting Plants, much depends on the specification called for, but it is satisfactory to note that the cost of treating plants has come down considerably in the last few years.

Preliminary Specification of a Creosoting Plant capable of treating 200,000 Metre Gauge Sleepers per annum for India.*

Capacity.

The plant will be capable of dealing annually with the following quantities of timber by the Lowry and Full Cell processes :—

200,000 metre gauge sleepers per annum of 250 working days assuming three charges per day,

and will consist of the following items :—

Cylinder.

This will be 6′ 6″ diameter by about 35′ 0″ long, constructed of riveted mild steel plates, and provided with a door at one end and a davit to swing it off. The door will be closed by means of strong hinged boiler screws. The cylinder will be provided with internal rails, extension rails, a guard rail to prevent the creosoting trucks from floating off, and two internal mild steel pipe headers with suitable heating pipes.

Suitable cross supporting girders, cradles, sliding supports and an efficient anchorage will be provided in order to carry the cylinder and also save all tanks to catch any overflow or drainage.

Creosoting Trucks.

Twelve mild steel creosoting trucks with cast steel wheels and roller bearings will be supplied ; they will be provided with removable solid bails to hold the sleepers down and to act as loading gauges.

Air Compressor and Vacuum Pump.

One horizontal duplex double-acting piston pattern pump, capable of raising the pressure of the creosote in the cylinder to 200 lbs. per square inch.

* This specification is taken from quotation by Messrs. Burt Boulton and Haywood, Ltd., Salisbury House, London Wall, E.C., to whom acknowledgments are due.

All valve discs will be made of cast iron, the spindles and springs will be of steel.

All the necessary throttle valves, sight feed lubricators, lagging, drain cocks, wrenches, etc., will be supplied.

PIPEWORK.

The necessary cast iron and mild steel pipework together with all valves, gauges, jointing materials, supports and hangers, steam traps, lagging, etc., will be supplied.

LADDERS, GALLERIES AND TRENCH COVERS.

Wherever necessary mild steel ladders, galleries and handrails will be supplied as well as chequered plate trench covers and curbs.

TANKS.

1. One measuring tank of sufficient capacity, calibrated to hold 500 gallons per foot of height. This tank will be supported on mild steel stanchions and bearers and fitted with a steam heating coil and an efficient float depth indicator, with a dial in the pump room to enable the operator at any moment to gauge the amount of oil drawn from or pumped into the tank.

2. One service tank of about 20,000 gallons capacity, provided with a suitable heating coil.

The tanks will be of riveted mild steel plates and will have light steel covers. They will be provided with internal and external climbing irons, manholes top and bottom and the necessary nozzles for connecting the pipework. There will be dipholes in the roof in order that the contents of the tanks may be measured.

BOILER.

One vertical boiler, of ample heating surface, fitted with a duplex feed pump and the necessary boiler mountings, lagging and firing irons to supply the steam required for the pumps and for heating purposes.

WEIGHING MACHINE.

One half-ton weighing machine by a reputable maker.

SPARE PARTS.

An ample supply of spare parts.

The specification for such a plant which is set out above is estimated to cost about £4,000 f.o.b. London. Such a plant is capable of dealing with about 100,000 B. G. sleepers or 200,000 M. G. sleepers per annum working three charges per day.

The cost of the yard lay-out, erection, importation, etc., would, of course, increase the capital cost of the plant, but the total should not exceed £10,000 or Rs. 1,50,000.

The total cost of a plant, to deal with over 500,000 B. G. sleepers, would be proportionately more, but less than in the direct ratio; Rs. 6,00,000 is considered a close estimate.

vii. Working Costs.

Based on the above figures, the following estimates of cost of treatment are given :—

I. Plant for treating 200,000 M. G. sleepers.

Plant capable of dealing with 200,000 M. G. sleepers annually at three charges per day.

Capital charges : --

	Rs.	A.	P.
Depreciation at 5 per cent. on Rs. 1,50,000	7,500	0	0
Interest on capital at 15 per cent.	22,500	0	0
	30,000	0	0
Charge per sleeper $\frac{30,000}{200,000}$	0	2	6

Wages Bill.

Unless close supervision is maintained over the labour, a good deal of waste may occur, but the superintendent, plant operators and coolies could, with proper management, be maintained on Rs. 1,100 per month exclusive of cost of loading and unloading sleepers from the stacks and treating trucks. This latter operation must be done by piece work for which ¼ anna per sleeper per operation is considered a suitable wage.

The cost of operation would, therefore, be :—

	Rs.	A.	P.
Wages $\frac{1,100 \times 12 \times 16}{200,000}$	0	1	0
Cost of loading and unloading trains at ¼ anna per operation .	0	0	3
Fuel per M. G. sleeper	0	0	6
Head office charges	0	1	0
Total .	0	2	9

WORKING CAPITAL.

This will vary with the amount and cost of oil used but may be estimated as follows :—

OPERATION COSTS.

	Rs.	A.	P.
16,660 M. G. sleepers per month at 0-2-9 say	3,000	0	0

OIL.

Reckoning one gall. of oil per M. G. sleeper at annas 12 per gall. (50 per cent. Creosote, 50 per cent. Earth Oil), say	12,500	0	0
	15,500	0	0
Capital required for three months' working. . . .	46,500	0	0
Say	50,000	0	0

The above estimate is based on the working of a commercial firm which would recoup its labour and oil expenditure after three months from the purchaser.

	Rs	A.	P.
Interest on working capital at 15 per cent.	7,500	0	0
Cost per M. G. sleeper $\frac{7,500}{200,000}$ . . . . . say	0	0	7

SUMMARY.

Capital charges	0	2	6
Labour, fuel and overhead	0	2	9
Working capital	0	0	7
Oil	0	12	0
TOTAL PER M. G. SLEEPER	1	1	10

Adzing and boring is not included in the above estimate but could be done for one anna per sleeper.

II. Plant for treating 100,000 B. G. sleepers.

For dealing with 100,000 B. G. sleepers, the expenditure is, practically, the same as regards plant capital and labour, but will be different for

working capital. The total cost, including adzing and boring and treatment with 2 gallons of oil at 12 as. per gall., works out at Rs. 2-5-6.

	Rs.	A.	P.
Depreciation at 5 per cent.	7,500	0	0
Interest at 15 per cent.	22,500	0	0
Interest on Rs. 1,00,000 working capital at 15 per cent.	15,000	0	0
	45,000	0	0
Capital charge per sleeper	0	7	0
Cost of treating (labour, fuel and overhead)	0	5	0
Loading and unloading trains	0	0	6
Adzing and boring	0	1	0
Oil, 2 galls. at 12 annas per gall.	1	8	0
TOTAL	2	5	6

III. Plant for treating 500,000 B. G. or 1,000,000 M. G. sleepers costing Rs. 6,00,000.

The labour, oil and working capital costs will be, approximately, the same as for smaller plant (although there will be some saving if the plant is kept working economically), but the capital charge will only be 0-3-0.

	Rs.	A.	P.
Depreciation at 5 per cent.	30,000	0	0
Interest at 15 per cent.	90,000	0	0
Cost per sleeper $\frac{90,000}{500,000}$	0	3	0

This shows a saving of annas 0-2-0 per B. G. sleeper and 0-1-0 per M. G. sleeper.

IV. Plant for treating 50,000 B. G. or 100,000 M. G. sleepers only.

As mentioned above, the pumps and boilers used in a plant to deal with 100,000 B. G. sleepers or 200,000 M. G. sleepers, annually, are the smallest commercially designed, so that the only saving would be on the treating cylinder and on the yard lay-out.

The cylinder would be only 20 ft. long. The plant itself would not cost less than £3,500 f.o.b. London or Rs. 52,500.

The yard lay-out would, certainly, cost another Rs. 50,000, making a total of not less than Rs. 1,00,000.

If we assume this to be the capital value of the plant in working order the annual charge per B. G. sleeper works out at 0-6-5 per B. G. sleeper and 0-3-0 per M. G. sleeper.

The working costs and charge for working capital will, certainly, not be less than for the larger plants, so that the extra cost over a plant

to deal with double the number of sleepers, annually, will be at least annas 0-1-5 and 0-0-9 for B. G. and M. G. sleepers respectively, and will more likely be 0-2-0 and 0-1-0 respectively.

It would, therefore, be quite as economical to put in the larger cylinder with the smaller yard lay-out and work the plant to its full capacity for half the time and then shut down. This method fully provides for expansion since it is much easier and more economical to enlarge the yard only, rather than to enlarge the yard and put in a second cylinder.

The same remarks apply, largely, to the installation of a cylinder to deal with 500,000 B. G. sleepers annually, with a yard lay-out to deal with 100,000 B. G. sleepers, but it is hardly conceivable that an area which is optimistically estimated to turn out 100,000 sleepers will eventually produce 500.000 or that the need for them will arise. Indian forests can seldom, unfortunately, be worked by intensive methods, and, therefore, very large areas have to be worked over to give even modest yields.

It would, therefore, appear that in general the smaller plants will be more useful for Indian conditions than the larger ones, although this generalisation would have to be considerably revised where floating streams could be made use of for collecting large quantities of sleepers. None of the above estimates include the provision for an adzing and boring machine.

APPENDIX A.

Analysis of the Creosote used in the experiments.

Appearance.—

Thick and dark brown in colour ; some crystals were separating.

Density at 26° C	1·065
Moisture	5·2 per cent.
Tar acids	6·5 per cent. (by volume).
Solubility	Almost completely soluble in benzene, insolubles amounted to 0·8 per cent.

Fractions.

Up to 190°	5·69% by weight.
190° to 205°	0·78 „
205° to 225°	6·41 „
225° to 235°	5·20 „
235° to 245°	5·91 „
245° to 255°	3·90 „
255° to 270°	8·40 „
270° to 290°	9·36 „
290° to 305°	8·91 „
305° to 315°	5·42 „
315° to 340°	14·70 „
Residue above 340° C. (by difference).	25·32
	100·00

Fractions passing between 305° and 340° were sulphonated and 4 per cent. by volume of these fractions remained unsulphonated.

APPENDIX B.

Analysis of the earth oil used in the experiments.

Appearance.—

Slightly thick, dark brown oil with a bluish florescence ; quite clear and transparent.

Moisture	Practically *nil*, about 0·1 per cent.
Solubility	Completely soluble in benzene.
Density	0·880 at 26° C.

Fractions.

Up to 170°	1·06%	by weight.
170° to 190°	0·68	"
190° to 205°	1·26	"
205° to 225°	1·09	"
225° to 235°	0·35	"
235° to 245°	0·45	"
245° to 255°	0·50	"
255° to 270°	1·45	"
270° to 290°	3·72	"
290° to 305°	4·07	"
305° to 315°	4·24	"
315° to 340°	15·73	"
Residue above 340° (by difference)	65·45	
	100·00	"

APPENDIX C.

Explanation of the formula from which the curves on page 98 are derived.

The curves are based on the formula

$$A = \frac{P(1+r)^n r}{(1+r)^n - 1}$$

in which A = annual economic cost.

P = amount of initial investment.

r = the rate of interest expressed decimally.

n = average life in years of the sleeper.

The annual economic cos is made up of two factors.

(1) The interest on first cost = Pr.

(2) The amount that must be set aside annually at compound interest r % to provide for renewal at the expiration of the life of the sleeper $= \frac{P \times r}{(1+r)^n - 1}$.

Therefore the annual cost $A = \frac{P \times r}{(1+r)^n - 1} + P \times r = \frac{P(1+r)^n r}{(1+r)^n - 1}$.

No account has been taken of the cost of Spikes, Bearing-plates, Labour cost or scrap value.

The annual cost of Spikes, Bearing-plates, etc., may be calculated from the same formula if their initial cost and anticipated life are assumed.

The scrap value of the sleepers will probably be too low to be taken into account. The cost of laying should be added to the initial cost of the sleeper.

M.G.I.P.D.—M—IV-4a-1—8-11-25—750.